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COMMENTS OF REACTOR DESIGNERS AND INDUSTRIAL REPRESENTATIVES ON THE PROPOSED EXPANDED CIVILIAN NUCLEAR POWER PROGRAM

JOINT COMMITTEE ON ATOMIC ENERGY

CONGRESS OF THE UNITED STATES

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FOREWORD

In August 1958 the Joint Committee on Atomic Energy published a draft of an accelerated civilian reactor program titled, "Proposed Expanded Civilian Nuclear Power Program." The proposed program was prepared by the Joint Committee staff based on discussions with the AEC and informal advice from a representative panel of reactor and industrial experts.[1] The draft program was prepared as the first step in the clarification of our nuclear power objectives, the need for which has long been recognized by the committee.

Although it was the intent of the committee to reach agreement with the AEC on a long-range program during the last session of Congress, the attainment of this objective was precluded by delays in the submission of AEC authorization legislation and numerous changes in AEC personnel. The draft program prepared by the committee staff was issued in August 1958 to permit early consideration of such a program by industry, and to facilitate informal discussions with the AEC and industry on the development of such a program before formal consideration during the 86th Congress.

After the draft program was issued the committee staff, at the request of the committee chairman and vice chairman, solicited specific comments on various portions of the program from industrial groups and reactor experts. The committee has received replies from a majority of the groups solicited. These replies, together with a general and a particular summary of the replies prepared by the committee staff, are being published in this committee print.

From a reading of a representative sample of the replies, together with the summaries, it is apparent that there are a number of points on which there is general agreement, and others where small and larger differences are manifested. There were one or two misconceptions which also should be corrected. A number of suggestions were made which would be of value in the further refinement of a balanced atomic power program.

There appeared to be almost unanimous agreement as to the need for an expanded program statement. There was also general agreement as to the objectives and scope of the program as well as to the need for the AEC to assert leadership in the implementation of the program, utilizing the participation of industry to the fullest extent. There was little dissent that the primary reason for the accelerated

[1] The panel consisted of Dr. Walter Zinn, president, General Nuclear Engineering Corp.; Dr. Henry de Wolf Smyth, chairman, board of scientific and engineering research, Princeton University; Dr. Chauncey Starr, president, American Nuclear Society and vice president, Atomics International; Mr. Titus LeClair, manager, research and development, Commonwealth Edison Co.; and Mr. James Grahl, director, atomic energy service, American Public Power Association (alternate for Mr. Samuel B. Morris, chairman, atomic energy committee, American Public Power Association).

program is to maintain United States leadership in atomic technology throughout the world.

As might have been expected, the principal differences arose as to the method of implementing the program. Some advocated greater Government direction and participation while others recommended greater reliance on private choice and particpiation. There seemed to be general agreement, however, that considerably greater Federal financial assistance was necessary in any event.

One misconception which should be corrected is that the program statement and list of projects were intended to be incorporated into legislation as such. It should be understood that the statement was proposed only as a guide for use by the AEC and Joint Committee in developing and recommending or approving particular policies and projects for executive or legislative implementation.

In addition to answers to specific questions, several general suggestions were received. Among these were the following:

1. Perhaps the objectives and program scope should distinguish more clearly between long-term and short-term purposes. This would permit a qualitative differentiation between such technical objectives as breeding and utilizing natural uranium, and short-term emphases as cheaper field assembly, and so forth.

2. Some more formal procedure should be established by AEC for an annual evaluation of the expanded program. The proposed program provided for reevaluation of each reactor concept at various stages, and especially before a determination of detailed design and construction. Moreover, the Joint Committee and its chairman and vice chairman have often recommended that AEC consult to a greater degree with industry as to its policies and projects. However, there would appear to be merit in the suggestions that some sort of an industry advisory committee should be used by AEC for review of its program and projects on a regular continuing basis.

We have requested the committee staff to continue to analyze all comments and suggestions in order to bring them to the attention of the committee. The tabular analysis at the end of this print is intended as a first step in this direction.

It is hoped that this committee print will be helpful in the coming months in developing an expanded atomic-power program which takes into account the views of industry, the executive branch, and the Congress.

CARL T. DURHAM,
Chairman.

CLINTON P. ANDERSON,
Vice Chairman.

STATEMENT

This document is a committee compendium prepared by the committee's staff and is not a committee report. It does not contain specific legislative recommendations, and is intended as a basis for further analysis and consideration by the members of the Joint Committee and the Congress.

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INTRODUCTION

Summary of Proposed Expanded Atomic Power Program

A draft statement of a proposed long-range program for the development of civilian nuclear power was published by the Joint Committee on Atomic Energy in August 1958. This statement, prepared by the Joint Committee staff, was issued as a Joint Committee print entitled, "Proposed Expanded Civilian Nuclear Power Program," dated August 1958.

The following is intended as a brief summary of the proposed program:

The draft statement is intended as a step in the development of a program which would be a logical extension of the 5-year experimental reactor development program sponsored by the Joint Committee in 1954. The proposed program is based on the technical and economic information obtained by Government and industry in the past 4 years and international developments which have made the international implications of civilian atomic power more clear and urgent.

Objectives.—The objectives of this program are to demonstrate economic nuclear power in the United States by 1970 and in "high cost" free-world nations by 1968. Achievement of these objectives is expected to fortify our worldwide position of leadership in the peaceful applications of atomic energy, particularly with regard to atomic power.

Implementation.—The program statement analyzes the technical progress needed to achieve economic nuclear power and outlines procedures to reach this goal. The work required may be divided into two general categories: (1) increased research and development, and (2) programed design, construction, and improvement of diversified nuclear powerplants. Present plans call for design studies during the next 5 to 7 years, of 21 reactor plants of many types; including 9 reactors of large size, 4 of intermediate size, 3 of small size and 5 small reactor experiments.

About half of the most promising designs would be carried through the construction stage. While the total capacity of plants to be built in this country is expected to amount to about 1 million electrical kilowatts, the purpose of the program is to develop information and not power per se.

Administration.—The following methods are described in the draft statement for accomplishment of the domestic program. The AEC would continue to direct and finance the major portion of reactor research and development as it has in the past.

Design and construction of reactors would be carried out (1) through an expanded and modified power reactor demonstration program of privately owned "second generation" plants, and (2) through

Government construction—by contract with private industry and non-Federal power organizations—of advanced experimental prototype plants and of other desirable plants not otherwise proceeding.

Provision is made for review of the adequacy of these arrangements and for consideration of additional alternatives.

International program.—The program also provides for cooperation with friendly nations in their programs for construction of nuclear powerplants. The Atomic Energy Commission would participate in research and development of American types of reactors to be constructed by free-world nations and would provide other assistance in connection with fuel cycles. Under the program proposed by Euratom, for example, about 6 plants would be built with a total capacity of about 1 million electrical kilowatts. Information developed in foreign participation programs would be made available to all American industry.

Program goal.—The proposed long-range program statement recognizes the importance to the United States Government of achieving the program objectives. The proposed program also stresses the need for positive direction of a clear-cut program to make certain the objectives are reached. It is intended to bridge the present gap between high cost first generation plants and economically competitive nuclear power which will supplement conventional fuels to meet expanding power requirements.

As soon as economic feasibility has been established, normal business incentives would stimulate greater industrial and financial participation and support activity. The ultimate goal of the entire program is to develop strictly commercial plants which would be economically competitive without financial assistance from the Government.

QUESTIONS AND SUMMARY OF REPLIES

I. QUESTIONS

The Joint Committee print titled "Proposed Expanded Civilian Nuclear Power Program," dated August 1958, was sent to reactor experts and industrial representatives for comment. Comment on certain specific aspects of the proposed program, in addition to any other opinions or views the addressee cared to provide on the proposed program, were solicited by letter by means of the following questions:

In addition to any other comments you may wish to make, please include your views on the following questions (pages refer to Joint Committee print of August 1958):

1. Do you agree with the three major objectives (p. 4) of the program? If not, what changes would you recommend?
2. Are the general technical objectives (p. 5) adequate? If not, what additions or deletions would you recommend?
3. Please comment on the adequacy of the scope of the technological program (p. 6).
4. In your opinion, is the proposed list of reactors in table I the best list for this program? If not, what changes would you recommend?
5. Do you consider the cost estimates (p. 8) to be reasonable? If not, please point out the areas in which you disagree.
6. What is your opinion of the policies on organization and administration proposed on page 9? Will they adequately implement the positive leadership required for success of the program?
7. If it should later prove necessary, what other types and amounts of assistance would you recommend for the domestic program? For the foreign program?

II. SUMMARY OF RESPONSES

As of December 3, 1958, of the 85 inquiries sent out, 69 replies were received. These replies are listed in the table of contents and printed in the appendixes.

The Joint Committee staff has prepared a brief summary of the replies. Since the proposed program covers numerous broad phases of policy and since many of the replies address themselves to different aspects of each, they are not readily amenable to a statistical summary. Therefore, the following narrative summary has been prepared to convey a general indication of the nature and substance of the replies. A tabular summary of each response to the various questions is set forth in the appendix following the replies.

Question 1. Major program objectives

The replies indicate a general agreement in the need for a clear-cut civilian nuclear-power program. The majority of the replies indicated general agreement with the basic objectives stated in the proposed program. Several recommended more specific definitions of the objectives and some stated that more general terms should be used.

The proposed program did not specify whether the 1970 goal for competitive power should apply nationwide or only to areas with high power costs. Some replies, however, recommended that the 1970 goal be set only for the high cost areas. Generally, the comments indicated some thought competitive power can be achieved sooner than the goals outlined while others thought it would be later. Several thought that the 2-year interval between attainment of economically competitive nuclear power in foreign countries and in the United States was too short.

Suggestions were also made to add as an objective an affirmative declaration that reactor development work would be carried out under the free-enterprise system. A suggestion was made that the development of economic breeding reactors be added as a primary objective while another reply deemphasized the importance of breeding during the time period of the proposed program.

Questions 2 and 3. Technical objectives and technological program

The consensus of comments on the technical objectives and technological program was that they were generally adequate and desirable. Comments on the technical objectives and technological program indicated a general agreement with the need for setting down such a program.

Several stressed the importance of keeping the technical program flexible with frequent reviews and revisions to reflect required changes in emphasis as the program proceeds. The need was stressed for establishing effective machinery for continuous evaluation of the results of the technical program and the overall energy problem so that successive steps will always reflect up-to-date knowledge.

Some responses suggested additional development projects such as (1) analysis of reactor safety requirements, (2) work on reactor plants which would use high-temperature reactor coolants as the prime mover working medium, and (3) work to reduce reactor plant operating costs. Greater emphasis on the development of low-temperature process heat reactors was also recommended.

Question 4. Reactor types proposed for development

Those who responded to this question indicated general agreement with the list of reactor projects. Some, however, believed work should be concentrated on a smaller number of reactor types while some suggested additional projects. Several of the replies expressed the opinion that greater emphasis should be placed on the construction of reactor experiments and prototype plants and that the number of large-scale reactor projects should be reduced. But the opinion was also expressed that large-scale reactors are required to furnish technical data and cost information not obtainable from smaller plants. Some replies favored concentration on development of a smaller number of preselected reactor concepts.

Additional reactor types were suggested such as the automatic boiling column reactor and a uranium hexafluoride reactor. Modifications of the reactor listing were suggested to emphasize particular reactor concepts such as breeding reactors, superheat reactors, and gas-cooled reactors. A suggestion was also made that only natural uranium and plutonium breeder reactors be considered for central station powerplants.

Concern was expressed in several of the responses relative to the listing of any group of developmental reactors by the Joint Committee. These replies indicated belief that the committee did not intend to restrict the choice of types. But they feared the mere listing of reactor types by the committee may lend such weight and authority to the list that necessary modifications, as might be indicated by latter work would be restricted. Several of the replies stressed the importance of providing flexibility in the reactor concepts to be developed in order that changes could be made to reflect information gained from the technical program.

Question 5. Program cost estimate

Most of the replies indicated belief that the estimated costs of the program were reasonable. Several stated that the estimates would probably be exceeded. Only one stated that the cost estimates were too high.

Question 6. Program organization and administration policies

The majority of the replies indicated complete agreement with the organization and implementation policies proposed for the program wherein the AEC would provide positive leadership and would assume responsibility for the direction of the program in which Federal funds are expended. Some thought, however, that the policies proposed gave too much authority to the AEC and suggested that additional provisions be included to increase industry participation in program direction.

Several stressed the need for setting up a technical evaluation group to provide the Commission and the Congress with a comprehensive technical basis for making the required decisions.

Several recommended that AEC reactor construction authority be limited to small reactors required for technical feasibility demonstrations. A few also objected to the establishment of deadlines for the submission of reactor project proposals to the AEC under the demonstration program and to the requirement that the AEC proceed with reactor construction when industry proposals are not received. On the other hand, objections were raised as to the alleged exclusion of cooperatives and municipalities from the proposed demonstration program. Extension of the second round power demonstration program so that cooperatives and municipalities could participate was recommended by several. Attention was also directed toward the desirability of permitting federally owned power systems, such as TVA, to participate in the demonstration program.

Question 7. Additional assistance needs

A number of responses indicated that additional forms of Government assistance probably would be required. Construction grants were recommended in several of the replies. Development of a system for providing grants for reactor plant construction and operation which would be equitable to both public and private power was recommended. A broader definition of research and development items was also recommended to increase the amount of Government support under the assistance policies outlined in the proposed program.

A few objections were voiced relative to certain forms of Government assistance, such as fuel charge waivers and waiver of capital charges for heavy water. It was argued, these forms of assistance artificially promote certain reactor concepts. Opposition to and recommendations in favor of changes in section 44 (preference policy) and 169 (antisubsidy) of the Atomic Energy Act were both expressed. A few indicated that the methods of assistance outlined in the proposed program were adequate and consideration of additional forms of assistance was unnecessary.

Solution to the problem of foreign third-party "liability" was considered to be of immediate and major importance if plants of United States manufacture or design are to be built abroad.

APPENDIXES

APPENDIX 1

REPLIES FROM EQUIPMENT COMPANIES

(NOTE.—Page numbers and reference to tables, etc., in the following letters refer to the Joint Committee publication of August 1958, entitled, "Proposed Expanded Civilian Nuclear Power Program.")

ALCO PRODUCTS, INC.,
Schenectady, N. Y., October 23, 1958.

Mr. JAMES T. RAMEY,
Executive Director, Congress of the United States,
Joint Committee on Atomic Energy, Washington, D. C.

DEAR MR. RAMEY: Since your letter of August 21 I have given the matter of the civilian nuclear-power program considerable thought, and in response to your invitation I should like to offer the following comments:

1. The basic assumptions as to the rate of development of power requirements and the consumption of fossil fuel reserves need very careful evaluation, since they are obviously the key factors in the development of the power program. The statement that power requirements will double every 10 years is one which I believe to be rather misleading if the published reports are carefully studied. While it is true that electric power consumption is growing rapidly, and has shown the 10-year doubling time for several years now, this fact alone is not sufficient. The total rate of energy consumption, of which electric power is only a part is the real key to the rate of fossil fuel consumption. The widely used references on energy consumption, such at Putnam, OEEC reports, etc., show the growth of total energy usage to be about 2 percent per year. These reports also show that sources of fossil fuel available at or near current prices are sufficient to last until nearly the turn of the century. It should be noted further that this heat energy can be used in plants that are more efficient and inherently less expensive structures than any of the nuclear powerplants contemplated today.

In the light of this it should be recognized that it is possible that the goal of 1970 may be optimistic, but this thought should not reduce the drive for development of economic nuclear powerplants. It is a long and difficult task and a degree of optimism in the planning is an essential ingredient if the program is to come to fruition by the time that we shall really need it. The uncertainty as to the time when the "other" uses of fossil fuels may become of major importance is, in my opinion, a factor which fundamentally supports the need for the recommended schedule of the development program.

2. I am in accord with the technological program and heartily endorse the small reactor concept as an excellent development tool. It should be accepted that these reactors may not prove as successful as initially anticipated, but it should also be accepted that the progress gained by focusing the effort will more than offset the shortcomings of any particular small reactor. In this regard I would point out that the "reactor experiment" concept was an attempt to develop this environment, but the attempt has been somewhat less than successful. History has shown that although the "reactor experiment" was based on the philosophy that "an experiment can fail, whereas a reactor cannot," large sums of money and many man-hours are spent doing research and development in order to prevent failure of the experiment. Admittedly, this problem is likely to be one of more concern to the executing agency than to Congress, but I feel that support of this, and understanding of it by the Congress, can encourage the proper atmosphere.

3. I believe that the proposed list of reactors needs most careful review by a technically competent engineering and scientific group. Many of those listed suffer from severe limitations of one form or another, and continuation of the

effort needs reappraisal. Such periodic reappraisals should be a major part of the program, with strong pressure being available to cut back on programs found wanting during these reviews.

4. The estimates of program cost appear adequate as a basis for initial planning. Undoubtedly, as experience is developed, some changes will be made.

I am in accord with the role of the Atomic Energy Commission in carrying on the base program of research and development with responsibility continuing through the small reactor plants. The small reactor construction stage is the time at which industrial participation could begin to develop.

The construction of large-scale plants and the pressure on the AEC to proceed with a program even in the absence of a satisfactory industrial proposal are two items that I do not support. Admittedly, the pressure to proceed without industrial support is qualified by "unless sufficient cause can be shown for the delay"; nevertheless, there does exist strong pressure on the AEC to proceed. I believe that the ability to defer or cancel a program should be strengthened so that it is easier to stop a program which develops no support if that lack of support is truly indicative that the program does not merit further effort.

Very truly yours,

KENNETH KASSCHAU,
Manager of Engineering—Atomic Energy.

ALLIS-CHALMERS MANUFACTURING CO.,
Milwaukee, Wis., October 30, 1958.

Mr. JAMES T. RAMEY,
Executive Director, Joint Committee on Atomic Energy,
Congress of the United States, Washington, D. C.

DEAR MR. RAMEY: Thank you for your letter of August 21, 1958, inviting our views and comments on the proposed expanded civilian nuclear-reactor program, dated August 1958.

Our comments on the questions in your letter are as follows:

1. The three major objectives (p. 4 of the committee memorandum) are desirable and we are in general agreement with them.

Based on the premise that the United States must maintain a position of world leadership in the peaceful applications of atomic energy, particularly with regard to power, the achievement and demonstration, by the United States, of competitive nuclear power is a necessity. While target dates are desirable for the objective, the situation indicates the need of achievement at the earliest practicable date.

Competitive nuclear power is a broad objective, and it must be kept in mind that competitiveness may be accomplished in some high-cost fuel areas in the United States and in some high-cost free world nations much earlier than the stated objective dates, and somewhat later in the low-cost fuel areas of the United States.

The timing of the achievement and demonstration of low-cost nuclear power in friendly, free world nations will depend on how much they really want our help and the extent of their cooperation with us in our efforts to help them.

2. The general technical objectives (p. 5) appear to be adequate to attack effectively the high capital costs of the plants and the fuel cycles.

3. The scope and permissible flexibility of the technological program appear adequate to accomplish the objectives.

Increased effort on the development and improvement of the fuel cycle is necessary to the success of the program.

The use of existing test facilities, including power reactors now being built, and the encouragement to private industry to construct test reactors to meet future requirements, will be beneficial.

With the stated objective of the program being information, not power, per se, it is essential that, as the program develops and the information is available, complete flexibility be permitted to change the sizes and types of reactors and number of reactors to be built.

4. The desirability of stating types, sizes, and approximate project dates (for those proving technically and economically desirable for construction) is recognized. It is difficult to say that this list, or modification of this list, is the best. The statements made on page 15 preceding the table of reactors must be kept in mind. Flexibility, based on technological advances, and constant review and

reappraisal is essential in order that the list of projects may at all times reflect an up-to-date evaluation and desirability of proceeding with the construction of any particular type and size of reactor.

5. Estimates of costs of any particular program must, of course, have the same flexibility as the specific projects to be undertaken. For the program suggested, the cost estimates appear reasonable.

6. It is our opinion that the organization and administration of the program should be the responsibility of the Atomic Energy Commission. The Commission should be permitted and encouraged to assume the leadership and positive direction of the program. Ways and means should be provided to encourage initiative and provide incentives for industry's complete cooperation. Industry should be encouraged to participate and propose power projects without rigid limitations as to whether they are in the program list or whether they are first or second generation plants, and their proposals should be evaluated as to their contribution to the objectives on a strictly competitive basis. Assistance to industry should not be restricted to a rigid list of reactor concepts and types.

In the selection by AEC of the reactors to be designed and constructed, more liberal consideration, than heretofore indicated, of time for submission, approval, and negotiations of contracts is needed for the encouragement of participation by industry.

7. This question appears to assume that the type and amounts of assistance presently provided are sufficient to attain the objectives of the program.

It is believed that a more realistic recognition of the nature of research and development is now necessary in order to obtain maximum benefits from industry's participation. While it is recognized a well-defined research and development program is desirable as an original objective in this area, a more liberal interpretation and acceptance on a broader basis of costs as research and development would be most beneficial to an early attainment of competitive nuclear power. Much of the high cost of nuclear powerplants now and for some time to come could properly be recognized in the research and development area, and the experimental nature of nuclear plants, even those classified as demonstration plants, should be recognized.

It is also believed that the stated objectives of such a program can ultimately be achieved at lower overall costs if further consideration is given to assistance to industry in the construction and operating areas. This philosophy was recognized by Senator Clinton P. Anderson in a speech last June.

Very truly yours,

R. M. CASPER.

ATOMICS INTERNATIONAL,
A DIVISION OF NORTH AMERICAN AVIATION, INC.,
November 3, 1958.

Hon. CARL T. DURHAM,
Chairman, Joint Committee on Atomic Energy,
Washington, D. C.

DEAR CHAIRMAN DURHAM: I have reviewed again the Joint Committee print entitled "Proposed Expanded Civilian Nuclear Reactor Program," dated August 1958. While I continue to be in complete accord with the major part of this program, I find that the passage of time has brought about a change in one detail that I would like to call to your attention.

Table I of the appendix, listing power reactors for new undertakings, includes an organic cooled reactor with an approximate electrical rating of 50 Mw. I believe that experience with this reactor type since the program was originally drafted indicates that construction of a larger plant is now appropriate.

Within recent months, Atomics International has completed extensive studies on large-scale organic reactor designs of an advanced type. A total of over $200,000 of company funds has been expended upon these analyses and designs. We have also completed a full year of operation of the AEC-sponsored organic moderated reactor experiment at the National Reactor Testing Station. The results of these studies and the OMRE operating experience have clearly demonstrated both the feasibility and the attractiveness of the organic concept for large central station plants.

In view of the studies already undertaken, I believe that the proposed reactor-construction program should be modified to increase the electrical rating of the

next organic reactor from 50 to 150 MWe. Such a plant would be a significant step in the development of this promising technology. The economic possibilities associated with this reactor approach would appear to warrant a continued research and development effort in parallel with the proposed construction program.

I appreciate the opportunity of commenting on the proposed program.

Sincerely yours,

NORTH AMERICAN AVIATION, INC.,
C. STARR, *Vice President.*

THE BABCOCK & WILCOX CO.,
New York, N. Y., October 28, 1958.

Mr. JAMES T. RAMEY,
Executive Director, Joint Committee on Atomic Energy,
Congress of the United States, Washington, D. C.

DEAR MR. RAMEY: I have reviewed and pondered over your letter of August 21, 1958, and the accompanying proposed expanded civilian nuclear power program. I am submitting my comments as an individual and not as an officer of The Babcock & Wilcox Co.

I am pleased that the joint committee has undertaken to formulate such a program and that it is providing such a careful study of a major subject which is of interest to the Government in relation to national and international policy, and also to industry which wishes and expects to perform its customary role in the development of this newly available source of energy.

My comments will be addressed to your questions under the same numbers.

1. The three objectives set forth on page 4 seem to me to be proper and adequate. The third objective, referring to United States leadership in the eyes of the world, requires the judgment of the Federal Government to determine its importance and the amount of effort which should be expended on it. It would seem to me to be an important objective in view of my contacts in Europe and Japan, and in light of my understanding of the international political situation.

Surely the first objective of planning for competitive power in the United States is in line with the American attitude toward research and development of new technology which promises to be of major importance. The development of energy for use in our present day civilization is very important, and nuclear power is a promising addition to our storehouse of potential energy.

If it were not for the international political situation it could be well argued that the demonstration of competitive power in the United States should follow a more leisurely course than completion by 1970 in view of our abundant supply of fossil fuel.

If the international situation would permit, I would prefer that the target date for competitive power in the United States be more flexible, say, between 1970 and 1980. A somewhat slower program would permit a more normal development, as has occurred in so many other areas, such as increased efficiency in steam power plants, automobile design and production, and other national developments.

2. I think the technical objectives listed on pages 5 and 6 adequately cover the subject and are entirely appropriate.

3. The scope of the technological program outlined on pages 6, 7, and 8 is adequate. I would hope that this program woud emphasize, wherever feasible, the desirability of building prototype reactors rather than the large ones "capable of generating several hundreds of thousands of electric kilowatts." Sometimes a large plant will provide information not available from a smaller one, but for the same expenditure more experience can usually be obtained from prototypes than from a fewer number of large units. It is impossible to be certain at this time how many large, intermediate, and small reactors should be undertaken, but I would definitely recommend that the fourth paragraph on page 8 be made more flexible and not state categorically

that 9 large-size reactors should be built in the next 5 to 7 years. For instance, in table I on page 16 there are listed 8 reactors of over 200,000 kilowatt capacity. If adequate study on these types indicates their probable success, then every effort should be made to plan for their construction in the size of approximately 50,000 kilowatts, even though the cost per kilowatt-hour as influenced by the small size would obviously be greater than for a large unit. If sufficiently promising, it would be better to have 2 prototypes simultaneously rather than have 1 large unit, which would necessarily reflect only 1 engineering solution to the problem. Operation of 2 prototypes by 2 different organizations is also promising, increasing the number of skilled operators and observers available to make the evalution for the type.

4. The reactor types listed in table I seem to cover the field adequately. There is, of course, no unanimity of opinion concerning the values of these widely different types, and for that reason it is appropriate that they be studied and, where promising, built and, wherever possible, in prototype size.

5. The estimated costs on page 8 are as good as possible today, except that if my recommendation for more prototype plants and less large ones were to be adopted the total construction cost could be somewhat less.

6. Referring to the three items in organization and administration on page 9, item (a) is very desirable.

It is difficult to agree entirely with the statement under the heading of (b) because it seems to me the problem is one of expecting AEC to assume leadership in the development program but at the same time it should not have or use dictatorial powers in its relationship with industry. It really is a question of permitting AEC to establish and maintain a desirable business atmosphere in order to accomplish the maximum of cooperation with industry. With unlimited power to direct the program, the judgment of interested parties in industry might be frustrated, and promising projects denied approval, especially when such projects might be of such doubtful immediate value that industry could not afford to make the investment, but at the same time the entire program could be greatly aided by Government support.

Again, the reference to "large-scale demonstration plants" should be very carefully considered and not undertaken for construction by AEC if a prototype plant gives reasonable promise of success.

Paragraph (c) seems to assume that AEC may find industry unable or unwilling to proceed with a suitable power demonstration program. This entire problem of construction by AEC really hinges upon the flexibility provided to AEC for assisting, in various degrees, the construction of uneconomic plants for the purpose of providing information for future work. I doubt if there would be any difficulty in having nearly all of these plants constructed and operated by private industry under a partnership arrangement with the Government for a much smaller cost than would result if AEC were to undertake the work directly.

The argument here is for more flexibility in the powers of AEC to undertake costs for desirable projects, than has been the case in the past in other power demonstration program proposals.

7. For the foreign program I believe the present Euratom plant is adequate.

For the domestic program I suggest a greater flexibility and partnership arrangements with industry for construction of untried reactor types, and a greater emphasis on prototype reactors.

The cost of "an expanded nuclear reactor program" will be greatly affected by the time assigned for its accomplishment. The schedule for the program proposed by the Joint Committee is a fast one. If this speed is required by the international political situation (and this is for Congress to determine) it is obvious that the cost should be largely underwritten by the Government. Without the international requirements, a much slower domestic program would be sufficient and there would be much less need for Government participation or subsidy.

Very truly yours,

ALFRED IDDLES.

BORG-WARNER CORP.,
Chicago, Ill., November 4, 1958.

Mr. JAMES T. RAMEY,
Executive Director, Joint Committee on Atomic Energy,
Washington, D. C.

DEAR MR. RAMEY: Your letter of August 21, with its attached memorandum on the proposed expanded civilian nuclear power program has been reviewed and accordingly we are pleased to comment on the questions you have raised in your letter.

The broad objectives stated in the first two paragraphs on page 1 of the memorandum certainly are desirable and should be backed by an adequate program to achieve these objectives. In general, we believe the program outlined should be adequate to do this.

Referring to the question in your letter, we offer the following comments:

1. The three program objectives outlined on page 4 appears to be fairly difficult goals to achieve within the time set but they seem reasonable for such a program. Possibly it would be useful for you to consider adding to this a more detailed definition of what nuclear power costs would have to be competitive with, both in the United States and in foreign areas. The variations in power costs within given large areas, such as the United States alone, or in Europe, are so great that it might be worth considering as an objective to reach nuclear power costs that would make it competitive in supplying some fixed percentage of the energy required for the area.

2. The 10 general technical objectives outlined, starting on page 5, appear to be well stated and we are pleased to note the emphasis on the development of lower cost manufacturing methods.

3. The scope of the technological program outlined, starting on page 6, covers all phases of reactor system and powerplant design and a wide variety of types of reactors. Such a program should achieve the objectives.

4. The proposed list of reactors on page 16, table I, certainly covers a wide range of major types of reactors. We note that a large proportion of these are proposed for a rating of 200 megawatts or more electrical output. Although we note that such large plants are generally scheduled for completion in 1965 and later, we believe it will be many years before all of the experience will be available from actual operating plants and that there is still a hazard. Unknown difficulties will possibly make it necessary to modernize and rework some of these plants long before their normal useful life would require. Possibly just as much technical progress could be made, at less expense, by building smaller plants.

5. Regarding the general cost estimates given on page 8, the costs appear to be reasonable but we would hold the reservation that depending on the problems encountered, some of the reactor types under consideration may result in higher costs.

6. Organization and administration of the program, as outlined on page 9, generally should produce the desired results. However, we would suggest that the wording contained in paragraphs B and C should be reconsidered because we believe every effort should be made to have a high degree of industry participation and that it should not be easy to go ahead and authorize large scale demonstration plants if industry does not readily concur. Lack of industry interest certainly would be considered as a measure of the economics of any large powerplant.

Referring to the cost estimates given at the top of page 9, we doubt that it would be possible to hold costs down to this estimate if the AEC should decide to go ahead and build plants without industry's support.

7. Regarding other types and amounts of assistance, we would suggest consideration of what might be learned from experience with plants now built and under construction. A few years of experience with regularly operating nuclear energy powerplants will be accumulating in the very near future. Possibly there should be consideration of independent study and analysis of the operating and maintenance experience of these plants. Also we should possibly anticipate the need for costly rework because of trouble, short life, or early obsolescence of some of the plants that will be in existence by 1965.

We sincerely hope that these comments are useful to you.

Very truly yours,

J. F. WEIFFENBACH,
Director, Research and Engineering.

GENERAL ELECTRIC CO.,
ATOMIC PRODUCTS DIVISION,
Schenectady, N. Y., October 31, 1958.

Mr. JAMES T. RAMEY,
Executive Director, Joint Committee on Atomic Energy,
Washington, D. C.

DEAR MR. RAMEY: In your letter of August 21, 1958, you requested my comments on the proposed expanded civilian nuclear power program, dated August 1958, prepared by the staff of the Joint Committee. This letter is in response to that request.

The general objectives of this program, outlined on page 4, will command widespread agreement. There may be differences as to precise dates but these are of secondary significance. The general objectives are, in my judgment, sound and possible of attainment by mutually supporting efforts on the part of Government (particularly the Joint Committee and the Commission) and industry.

As you know, General Electric has formulated a plan looking toward attainment of economic nuclear power by development of the boiling-water design. We envision this plan as one part of a broad national effort to achieve the program objectives outlined in the staff report. Brief descriptions of the two parts of the General Electric plan for development of the boiling-water approach, the technical program and the field experience program, are attached.

1. I have several specific comments about the staff report from a technical point of view.

First, in determining the number of reactor concepts to be pursued, a distinction should be made, as the report indicates, between the research and development stage (including construction of critical experiments) and the subsequent stages of construction of prototypes and construction of large-scale reactors. It is desirable that the research and development effort should be conducted along a broad front and that a wide range of concepts be explored through this stage to determine their further promise.

The report indicates that perhaps half of the concepts now under consideration will probably not prove desirable for construction. The number of types which should be pursued through the stages of prototype and large-scale reactor construction and the selection of types are matters about which opinions will differ. I do not suggest that the boiling water reactor is the only one which can or should be developed. On the other hand, better results will be obtained faster and less expensively if, in the construction stages, time, talent, and money are concentrated on a small number of the more promising types. Such a development in depth approach seems to me sounder than a dispersion of effort among even half the types listed in table 1 of the report.

How many types should be pursued beyond the research and development stage depends in large part on how much money can be made available. However, I do not believe that construction funds should be devoted to a given type unless (*a*) its technical feasibility has been demonstrated, (*b*) there is reasonable assurance that further development would be worthwhile, and (*c*) it is possible to outline a clearcut course of action for further exploration which gives reasonable promise of attaining competitive power.

Second, if it is intended to explore a range of basic types as extensive as that indicated in the report, and if this exploration is to continue through several generations of intermediate size and full-scale reactors, then it is probable that the indicated program cost of $875,000,000 will be substantially exceeded. On the other hand, with concentration on a small number of types and with a proper balance between full-scale plants and small and medium sizes, I believe that the indicated program cost should prove realistic.

Third, the 10 general technical objectives of the program are all desirable. However, the principal value of any statement of technical objectives lies in their providing direction for research and development programs. Necessarily, the 10 objectives vary in degree of importance and urgency. Because of this, and because of their generality, they cannot serve as specific guides to the formulation from year to year of the research and development programs of the Commission. On the other hand, if objectives are to be stated in more concrete terms, they must be revised periodically in the light of technical developments.

It would be desirable if the Commission were to state, subject to periodic revision, the specific objectives of its developmental programs. It would also be desirable if, in framing these objectives, the Commission were to establish regular mechanisms for obtaining the views of industry.

Fourth, if Government-owned prototypes are to be part of the program, careful consideration should be given in each case to the technical value of adding electric power-generating facilities. In some few cases, such facilities might be useful in gaining additional knowledge. Generally, however, they would add very little in the way of new knowledge.

Fifth, the construction of large scale plants with associated generating facilities is an indispensable step in demonstrating the economic feasibility of nuclear power. The key problem here is timing. As the report recognizes, small or medium-size plants may, in some cases, permit greater technical progress. Cost-reducing variations in design may often involve a degree of speculativeness even when the basic technology is well established. Using smaller scale plants to explore novel features will often be a faster as well as a more prudent route to the desired information.

Sixth, the report properly emphasizes the importance of developmental work on the fuel cycle. This work should include both *general* and *specific* fuel developments. For example, research on the properties of materials, the development of new types of materials, and certain basic physics measurements, are *generally* useful. However, the evolution of an economic, reliable fuel involves optimization of the whole reactor system and its operating conditions in conjunction with the fuel—and also extensive statistical testing of fuel. As a consequence, a major part of the effort (in terms of cost) should, as the report recognizes, be devoted to fuels for *specific* reactor designs rather than to "general" fuel development.

In summary, the report delineates the problems and sets objectives. My suggestions are as to particulars, and not as to basic objectives.

2. The second major aspect of the report relates to the respective roles of Government and industry in the attainment of economic nuclear power.

First, a basic premise of the report is that both have major roles to play. There should be general agreement with this premise.

Second, another fundamental premise of the report is that the Commission should continue to be responsible for the base program of research and development through its national laboratories, industrial contractors, universities, and nonprofit institutions. Here again there will be broad agreement. The simple economic reality is that it will be some time before there will be sufficient equipment business to permit industry to carry the total research and development burden. In the long run, of course, with the development of major equipment business, industry should bear the principal share of the research and development effort.

In this connection, the development of a healthy, self-sufficient atomic industry would be promoted if a greater proportion of Commission-financed development work were placed in non-Government and particularly industrial laboratories. To the extent that major reliance is placed on the national laboratories to conduct basic research and development, the growth of a sound industry will be retarded and it will be necessary to rely on Government aid for a longer period than would otherwise be the case.

The Commission's research and development activities should include not only basic work in such fields as physics, chemistry, and metallurgy, but also exploration of specific reactor concepts. Construction of critical experiments would be a necessary part of this exploration. In this stage, as distinct from the subsequent construction stage, the emphasis should be on a broad range of types.

Third, it is my conviction that the country will obtain better results if basic decisions such as the selection of reactor types are made by independent, competing, risk-taking groups rather than on a centralized basis. I do not believe it is possible, for example, to develop on an a priori basis an ideal list of basic types which should be explored through the construction stages. Also, I do not believe that it is possible to find in any one body, no matter how well qualified, the all-embracing wisdom necessary to make the large number of evalutions and technical decisions involved in a broad and complex program such as that contemplated in the staff report. To my mind, the soundest approach is decentralized decisionmaking by a number of independent, competing groups, each learning from its own mistakes and each reaping profit or loss from its successes and failures.

Fourth, the Government must decide whether the national interest requires that the taxpayers' funds should be used for the construction of large-scale nuclear powerplants. If they are to be so used, I believe that Government aid will lead to faster progress with fewer disadvantages than Government ownership.

With private contributions to the cost of the plant, more plants can be built for any given level of Government appropriations. Moreover, Government aid can be on the basis of some risk to the private participants in the project and it, therefore, provides greater incentive to cost cutting and improved efficiency. Again, Government aid can be administered to permit independent, decentralized decisionmaking. Finally, Government aid, unlike Government ownership, could, if provided equitably, avoid the public-private power controversy and reduce the fear that an atomic acceleration program might increase the long-term role of Government in the power industry.

Fifth, of all the forms of Government aid thus far suggested, I believe that the method suggested at page 12 of the report, namely, Government contribution of a portion of the estimated difference between the cost of a conventional plant and the cost of a nuclear plant, is the most desirable. Waiver of use charges for fuel, guaranteed plutonium prices, and loan of heavy water without charge, tend to bias the technology. Other forms of aid, such as performance of research and development in Commission laboratories, or research and development contracts under section 31 (a) of the 1954 act, may not be adequate to enlist the broadest possible private effort and are more difficult to administer equitably as among different groups.

3. On the international side, I believe that the proposed program of cooperation with Euratom is sound and that other forms of aid are not needed. As my letter of July 11, 1958, indicates, this program has my general endorsement. However, in implementing the program I believe it desirable to clarify the complex and difficult fuel cycle guaranty arrangements (see pp. 4–7 of my July 11 letter), and to reduce administrative review and approvals to the minimum.

The staff and its consultants have produced a careful and comprehensive analysis of the problems of nuclear power development in the United States. By identifying and focusing attention on the major technical and policy issues, the staff paper should serve as an invaluable guide to the Joint Committee and industry and as a basis for orderly, intelligent, and objective discussion and resolution of major issues of national atomic policy. I should like to express my appreciation to you and your associates for a job well done.

Sincerely yours,

FRANCIS K. MCCUNE,
Vice President and General Manager.

A SUMMARY OF OPERATION SUNRISE

AN ACCELERATED ATOMIC TECHNICAL DEVELOPMENT PROGRAM TO REACH COMPETITIVE NUCLEAR POWER IN 7 YEARS

Atomic Power Equipment Department, General Electric Co.

WHAT IT IS

Operation Sunrise is a program for the *development in depth* of boiling water reactor systems to reach competitive nuclear power in 7 years. It is a program that begins with the results of solid experience and proceeds in a straight line toward a reasonable and attainable goal.

Specifically, the program includes:

1. A group of small and medium "developmental" nuclear powerplants, to be in operation by 1962, which will provide technology leading to competitive nuclear power.
2. "Evolutionary" plants, to be in operation by 1965, which will be competitive in their locations. These plants will produce power for under 8½ mills per kilowatt-hour.
3. "Target" plants, to be in operation by 1970, which will be competitive with 25 percent of the conventional plants then being installed in the United States. The larger plants will produce power for approximately 6½ mills per kilowatt-hour.
4. Supporting research, development, and testing to make this possible.

TECHNICAL FOUNDATION

The program presented here is the result of a major effort by the General Electric Co. to analyze the best course to competitive nuclear powerplants in the United States. This effort has involved design studies covering promising reactor systems; analysis of the results of reactor programs to date; analysis of

the development still required to support advanced designs; and evaluation of the performance and economics of each system.

From these studies we have concluded that current technology is now ready to support an intensive development program; that fusion is still only a long-range hope; that the cycle from research and invention to operating proof is long; and that the way to get competitive nuclear power is through the same kind of hard evolutionary work that got us automobiles, airplanes, and steam turbines.

Boiling water reactor ready for intensive development

An intensive development program can be proposed for any single reactor type at this time only if the reactor is technically on solid ground now, if it promises clearly that further exploration is worth while, and if it affords a clear course of action toward the realization of that promise. We are convinced that the boiling water reactor meets these conditions better than any other type, and for these reasons:

The technological foundation is established for the boiling water reactor. We have experimental data, design and construction experience, and operating information from five "first generation" boiling water reactors. Boiling water reactors at Vallecitos and the Argonne National Laboratory are operating successfully, producing more power than expected. In addition, the large-scale Dresden station will be complete in 1960.

The safety characteristics of the boiling water reactor have been proved in the AEC's Borax and SPERT experiments, the only series of comprehensive safety experiments that have been performed for any type of reactor to date.

The low-enrichment, uranium-oxide fuels have demonstrated their feasibility for commercial service. Feasible manufacturing processes are developed; oxide fuel is corrosion resistant and stable under irradiation; and many opportunities exist for further cost reductions.

The lowest capital costs of all proven reactors are those of boiling water reactors. We have also been able to predict construction costs accurately. Dresden is proceeding within the original budget; the Vallecitos boiling water reactor was completed under budget.

The boiling water reactor is the leading contender for competitive nuclear power today, and it is sufficiently adaptable to remain so into the foreseeable future. Its cost advantage, vast background of technology, momentum of current development programs, and potential for improvement assure the boiling water reactor of attaining competitive nuclear power considerably ahead of any other type. As the preferred system becomes more obvious, moreover, the likelihood that the second, third, or lower runners will have the necessary development invested in them will fall off drastically.

Therefore, Operation Sunrise is a program for the concentrated development of boiling water reactor systems to reach competitive nuclear power. It is based on the concept of development in depth of a single reactor type rather than development in multiple of many different reactor types. We offer you no magic shortcut, but we do offer an orderly marshaling of resources and experience, removing the remaining technological obstacles in the path of economic power at minimum cost and without excessive technological or financial risks.

FUTURE TECHNICAL OBJECTIVES

The boiling water reactor is now capable of attaining a series of five significant technical objectives, the proper blend of which will lead directly to competitive nuclear plants:

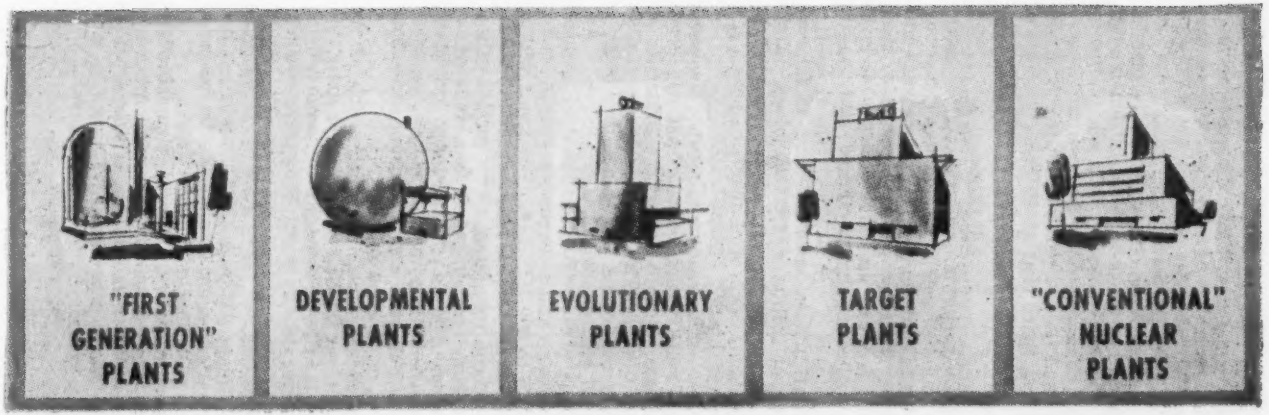
1. Increased power density: A doubling in the power output from the present 30 kilowatts per liter of reactor core volume to 60 kilowatts per liter.

2. Reduction in plant complexity: The nuclear steam supply system can be simplified, the plant layout can be made more compact, and containment costs can be reduced.

3. Improvement in steam conditions to increase thermal efficiency from the present 28 percent to over 31 percent with saturated steam or to 35 percent with superheating.

4. Increased plant size from the present practical limit of 200,000 kilowatts for a saturated steam station to over 450,000 kilowatts for a superheated steam plant.

5. Improved fuel performance through the development of reliable fuel performance for exposures of up to 15,000 megawatt-days per ton.



FIVE STAGES IN TECHNICAL DEVELOPMENT—"First generation" boiling water reactors now operating; separate series of Developmental Plants, Evolutionary Plants, and Target Plants; and finally "Conventional" nuclear plants which generate power below fossil fuel costs.

Blend of objectives required

If we could realize all these potential gains *simultaneously*, we would be well in the clear toward achieving economic nuclear power. Actually, attainment of any one of these objectives can be reached *now*, but only by some degree compromise with one or more of the other objectives. For example, plant simplification will not at first be easily reconciled with improved heat rates.

Nevertheless, we can see ways in which all of these objectives can be blended in an eventual nuclear powerplant. To put all of the possible improvements into the "next plant" would be premature. The likelihood of an accumulation of "bugs," leading to expensive delays and changes, would be great. These is abundant experience that the overall cost and time to patch up an overly speculative step can easily turn out to be several times that of an orderly series of modest steps.

"DEVELOPMENTAL" PLANTS

The heart of Operation Sunrise—and its major immediate activity—is the design, construction, and operation of a round of small- and medium-sized "developmental" boiling reactor plants to extend the technology, to reduce costs, and to lead the way to further cost reductions. It is important to recognize them clearly as *pilot plants*, since they will test features useful or decisive for large plants, but which might not be important to a small plant viewed as an end in itself.

There are seven possible "developmental" plants, each intended to improve and test a specific combination of phases of boiling water technology. From our current vantage point, we estimate that only *five* of these plants need be built. Although various combinations of plant types and sizes are possible, a typical combination of developmental plants is this:

1. *A 50 MW (e) natural circulation boiler.*—This plant will provide the bases for developing a reactor line of extreme simplicity and low-cost that will serve a market in the range of 10 to 150 megawatts. It will exploit the simplicity of the "pot-pipe-turbine" concept of reactor design. This is the Humboldt Bay reactor to be operated by the Pacific Gas & Electric Co. Since this plant is already committed, only four developmental plants remain.

2. *A 25 MW (e) "compact" plant.*—This plant will pilot our developments directed toward attaining the ultimate in design and construction simplicity for forced circulation plants in the range of 75 to 300 MW (e). The plant will be physically compact through the employment of an internal pump and recirculating loop, internal steam separation, and a novel control system. One version of this plant has been designed to utilize the "hook-on" principle, and thus make use of a substantial portion of conventional equipment in an existing fossil fuel plant.

3. *A 25 MW (e) high power density plant.*—This plant will test our technical objective of at least doubling the steam output from a given reactor core—thus reducing unit capital costs for large forced circulation reactors.

4. *A 100 ME (e) high power density plant.*—Extending the results of the preceding plant in the series, this plant will test the limits of power density that can be obtained in a medium-sized reactor; it will also provide a full-scale proving out and improvement program on high power density fuel. This plant could be rated as high as 250 MW (e).

5. *A 50 MW (e) separate nuclear superheater.*—It could most advantageously be "hooked on" to an existing boiling water plant. This installation will test and demonstrate our ability to improve thermal efficiency through the technique of nuclear superheat and thus realize another of our technical objectives.

Specific development tasks are required to advance the novel design characteristics of each plant. There will also be a limited amount of basic exploratory research. (See table.) *The important conclusion is that the remaining effort is much smaller than that which has already been expended.*

Developmental plant-types (illustrative combination)—Technical summary

Development plant type and nominal rating	Range of ratings available	Date of start of detail design [1]	Date of start of operation	Principal technical features	Typical research and development tasks [2]
	Megawatts				
1. 50-megawatt natural circulation.	50–60	1959	1962	1. System simplification. 2. Largest natural circulation boiler to date. 3. Simplified containment.	1. Steam separation. 2. Pressure drop in core. 3. Pool-type containment. 4. Transient and stability analysis.
2. 25-megawatt compact.	5–25	1959	1961	1. Reduction in physical size. 2. Forced circulation with internal pump. 3. Internal steam separation. 4. Novel control system.	1. Steam separation. 2. Internal pump test. 3. Operation with high void content. 4. Compatible control system.
3. 25-megawatt high power density.	5–50	1959	1961	1. Doubling of power density. 2. Reduced cost of reactor vessel and internals. 3. Forced circulation. 4. Improved fuel.	1. Increased pressure. 2. High-power fuel. 3. Improved pumps. 4. Close coupled layout.
4. 100-megawatt high power density.	100–250	1962	1965	1. Test of increased power density in large plants. 2. Fuel improvement. 3. Forced circulation.	1. Further fuel development. 2. Stability. 3. Reactivity control. 4. Improved pumps.
5. 50-megawatt separate superheater.	10–100	1960	1963	1. Test of superheater principles. 2. Separate superheater can be used as "hook-on" reactor. 3. Integral superheater is alternate plant in program.	1. Design of fule and core assemblies. 2. Materials test for high-temperature operation. 3. Transient load matching. 4. Control of superheater fuel erosion and corrosion. 5. Integration of combined reactor designs.
All plants (general areas of development contributing to all plants).	----------	[3]	----------	----------	1. Improved fuel. 2. Determination of maximum power limits. 3. Reactor physics and control. 4. Control of radioactive materials transport. 5. Improvement in operations and simplified containment.

[1] In all cases, preliminary and scope design, and key research and development tasks can start immediately.
[2] Includes some work necessary to extend each concept into its subsequent evolutionary plants.
[3] Can start key tasks immediately.

The first plant of this combination of five developmental plants has already been committed, and will be completed in 1962. We are prepared now to proceed with design and construction of the other four developmental plants immediately, along with the necessary associated research and development tasks. We could place the superheater plant in operation in 1963, and the compact and the smaller high-power density plants in operation by the end of 1961.

EVOLUTIONARY PLANTS

The experience gained with the developmental plants and their supporting development programs will make it possible to proceed directly to the next major step in Operation Sunrise—medium- and large-scale evolutionary plants. The purpose of these plants is to act as a bridge between the developmental plants and the much larger and more sophisticated target plants to follow. They are necessary as an intermediate and risk-reducing step.

Three possible lines of evolutionary plants and their nominal ratings are these:

1. A 100-MW (a) natural circulation boiler, with internal circulation and internal steam separation. This plant will demonstrate the extension of the upper limit of rating for a self-contained natural circulation reactor system.

2. A 200-MW (a) forced circulation boiler, single cycle, with close-coupled recirculation loops, high power density in a large core, and high-pressure saturated steam. This plant will provide full-scale operational experience with the cost saving results of the high power density and compact plants in the developmental series.

3. A 325-MW (e) boiler-superheater combination. This plant will furnish design, construction, and operating experience with the first nuclear superheating reactor of economic size. The plant will also afford a full-scale fuel-improvement program for superheat conditions. Typical superheated steam conditions will be 900° F. and 915 pounds per square inch. The plant will have a heat rate of 9,500 B. t. u. per kilowatt-hour.

Although the 3 evolutionary plants will not be of the maximum practical size, and thus will not have the lowest attainable unit *capital* cost, they will be large enough to demonstrate fuel costs in the range of 2 to 2½ mills per kilowatt-hour. Their total power cost will be under 8½ mills per kilowatt-hour, making them economically competitive in selected locations with fossil-fueled plants going into service during the 1960's. Moreover, they will possess inherent possibilities for reduction of fuel and operating costs during a considerable portion of plant life.

TARGET PLANTS

The plants following the evolutionary plants will be target plants, which will show better costs than the evolutionary plants because of their increase in unit rating, increase in scale of manufacturing and construction operations, and simplification in design, manufacturing, and operating procedures, based on an aggregate of more than 20 reactor-years of operation. For this series also we see 3 lines of plants corresponding to the 3 lines of evolutionary-plant lines in type and size range.

To cite an example, one possible target plant is a 450-megawatt high-power density plant with a separate superheater and with the whole system housed in a low-pressure containment structure.

The target plants will have capital costs in the range of $175 to $225 per kilowatt (at today's dollar values) and fuel costs in the range of 1.7 to 2.2 mills per kilowatt-hour. This leads to total power costs as low as 6½ mills per kilowatt-hour for the largest units.[1]

Even these target plants are not the end of improvement and development of nuclear power, as they themselves will undoubtedly open new roads which will lead to still further power-cost reductions in plants to follow. At this stage, atomic powerplants will have become "convenitonal" nuclear plants in the true sense of the word.

THE COST OF OPERATION SUNRISE

We have defined a program which will place competitive nuclear power in the industry in the next 7 years. The question which now arise are: "What is the cost of the program?" and "What are the packages which must be purchased?" The total gross cost of Operation Sunrise is $128 million. This $128 million includes about $90 million for the construction of 4 new "developmental" boiling-water plants and $38 million for the research, development, and test activities required to design and build those plants and to extend their concepts into the evolutionary plants to follow. This figure does not include the cost of the evolutionary or target plants, because those plants, wherever they are built, will be economically justified as a conventional plant would be.

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[1] Based on 0.70 load factor and 14 percent capital charges.

We estimate that at least $10 million of the $38 million required for research and development activities can be defrayed by utilizing a part of the results of the Government's atomic research, which are available to all who wish it. This $10 million represents the estimated cost of information likely to be forthcoming from AEC research programs which can be applied to Operation Sunrise over the next 7 years.

A second source of research and development support needed by the program is General Electric itself. In addition to the investment which has already been made in facilities and in basic development work, General Electric will contribute additional development work to this program to the extent of $7 million in direct costs over the next 7 years. Thus, the net cost of the research and development programs to utilities would be $38 million, less $17 million, after making allowance for the equivalent value of the AEC-developed information and the General Electric contribution, or $21 million.

Following is a summary of the estimated costs to utilities of 7 alternate developmental plants, including the supporting development work, over the 7-year period. The total cost and the average cost assume that 4 new developmental plants would be built in addition to the 50-megawatt natural circulation plant, which is already underway. This summary indicates that the typical cost would be about 111 million, including $21 million of supporting development.

Developmental plant costs (includes supporting research, development, and test)[1]

[Estimated cost (millions of dollars)]

	Plant cost	Research and development	Total
Illustrative combination:			
50-megawatt natural circulation	(2)	[2] 4.5	[2] 4.5
25-megawatt compact	12.5	2.5	15.0
25-megawatt high power density	14.5	2.5	17.0
100-megawatt high power density	36.0	3.0	39.0
50-megawatt separate superheater [3]	20.0	8.0	28.0
Total cost [4]	83.0	20.5	103.5
Other alternates:			
100-megawatt compact	32.0	3.0	35.0
50-megawatt integral superheater	22.5	7.0	29.5
Average cost of typical combination [4]	90.0	21.0	111.0

[1] Research and development costs include work necessary to extend each concept into its subsequent evolutionary plants. Research and development costs subject to adjustment depending on the exact combination of plants built.

[2] Over and above the existing commitment by P. G. & E. for a natural circulation plant. P. G. & E. commitment not included in the totals, which represent only additional investment beyond current programs.

[3] Assumed to be hook-on to an existing plant. Superheater cost only.

[4] Not including plant operating costs and initial fuel inventory expense of $10,000,000.

THE IMMEDIATE PROGRAM

We have laid before you a summary of Operation Sunrise, indicating the proposed plants, their estimated cost, and the supporting packages of research, development, and testing which are required.

We ask you to consider what role your company might play in Operation Sunrise, including the following possible steps:

Those utilities with the larger electric plant investments might consider purchasing one of the developmental plants with its associated research and development activity. Those with lesser plant investment, or with substantial investment at present in nuclear programs, might want to consider joining in groups to undertake one of the other developmental plant programs. We will welcome the opportunity to present to you additional details on the various programs which are possible. Various forms of financial and research assistance are available to utilities under Government programs. We are prepared to work with you to define the areas which might be eligible for such assistance if you desire it.

SUMMARY

1. The achievement of competitive nuclear power must follow the normal course of evolutionary improvement with a reactor type which is on solid ground now and which offers important potential for future improvement. The boiling water reactor meets these conditions.

2. The path to competitive nuclear power has been plotted by comprehensive study. It is a practical course and can be carried out for predictable amounts of money and within a predictable time.

3. The major steps which now need to be taken are the construction of developmental plants, followed by evolutionary plants and target plants.

4. Upon completion of Operation Sunrise, the industry will have available modern, nuclear plants which will be competitive with 25 percent of the conventional plants then being installed in the United States. They will cover a range of ratings up to 450,000 kilowatts per unit.

An Accelerated Atomic Field Experience Program

OPERATION KNOW-HOW HELPS UTILITIES BUILD EXPERIENCE, PRESTIGE, AND PUBLIC ACCEPTANCE FOR ATOMIC POWER GENERATION

THE PLAN

Industry is at work now to produce profitable nuclear power by 1965. However, even if atomic technology permits us to develop this rapidly,the transition to atomic power generation could be delayed much longer by a lack of trained operating personnel, confusion regarding local and national regulatory statutes and indifferent public reaction.

The electrical manufacturing and electric utility industries working closely together can, and rightfully should, play the leading role in the development of nuclear power generation. General Electric's proposed accelerated field experience program, named "Operation Know-How," provides the opportunity for the entire electrical industry to play an active part in this technological breakthrough. Here's how private enterprise can assume the initiative.

General Electric is prepared to construct a number of small (5,000 kilowatts) nuclear powerplants based on experience with the Vallecitos boiling water reactor. By building a reasonable number of these pilot plants of the same design, unit cost can be established at a practical level. Delivery of equipment for the first unit can be made in 18 months. *This means electric utilities could be operating their own nuclear powerplants in 1960.*

ADVANTAGES TO UTILITIES

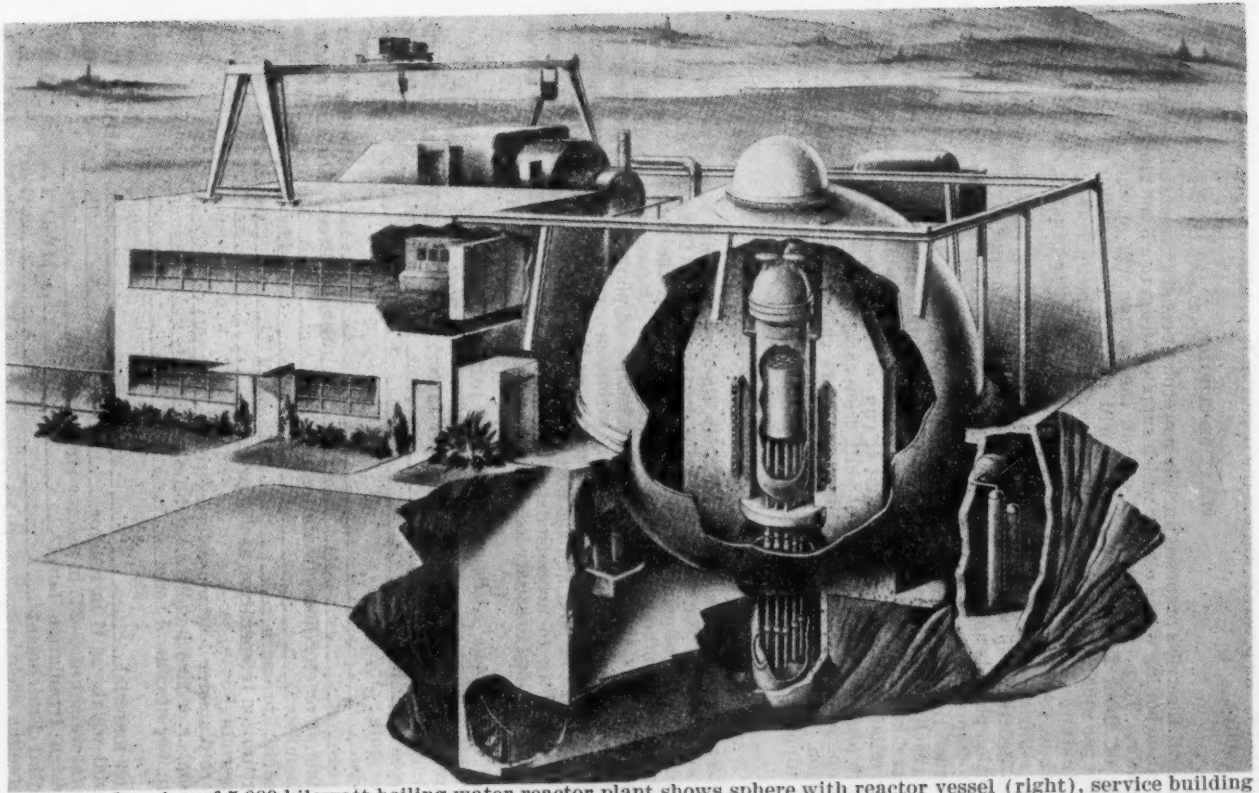
Operation of the proposed 5,000-kilowatt boiling water reactor plant can offer significant contributions to electric utilities and their communities. For example:

1. When profitable nuclear power generation becomes a reality, electric utilities will have experienced and licensed personnel in their engineering, administrative, and operating areas. Moreover, utilities will have had an opportunity to test components, fuel types, waste disposal methods, and other facets of atomic power generation.

2. Opening the plant continuously to the public can accelerate acceptance through providing an opportunity for the public to obtain firsthand information about nuclear power generation, getting it out of the mystery realm. In so doing, electric utilities can make a major contribution to education of the youth, the educators, and the businessmen in local areas.

3. Construction of a small plant now will advance relations with national and local regulatory bodies. Operation of these plants by a number of utilities across the country will encourage the acceleration of regulatory decisions concerning nuclear plants and can help unify the thinking of these agencies.

4. The Accelerated Field Experience Program can introduce atomic power to the Nation on a wide scale, in minimum time, at minimum cost. It provides an opportunity now to demonstrate to the public and local government the utilities' role in developing peacetime nuclear power.



Cutaway drawing of 5,000-kilowatt boiling water reactor plant shows sphere with reactor vessel (right), service building (left), turbine-generator area at rear of service building. Space surrounding sphere below ground level houses nuclear steam supply system components

5. These small community powerplants will more fully assure the proper support and understanding of local investors, regulatory commissions, security analysts, and others involved in supplying capital for this rapidly growing industry.

6. Finally, the program affords the opportunity to establish working insurance relationships.

PLANT DESCRIPTION

General Electric's proposed nuclear powerplant consists essentially of a natural circulation boiling water reactor which supplies steam to a 5,000 kilowatt turbine-generator. To provide its rated output, the reactor will operate at a thermal power of about 22,000 kilowatts and will produce about 66,000 pounds of 650 pounds per square inch saturated steam per hour. The nuclear plant, as depicted in the cutaway drawing can be furnished as a complete package, erected on the utility site, ready to operate.

The addition of an attractively landscaped plant site, complete with recreational facilities, can subtly serve to show your customers that a nuclear power generation plant is not a dangerous neighbor. These scenic surroundings can also serve to impress as well as educate visitors.

Because the proposed plants are related in concept to the Vallecitos boiling water reactor, utilities can benefit from its operating experience. For example, construction of the VBWR has proven that this type of plant can produce electric power reliably and safely, and that it can be easily operated and maintained. For the proposed plant, a typical shift crew consisting of a foreman, 2 reactor plant operators and 2 turbine plant operators can easily handle normal plant operation. Maintenance work can be accomplished using conventional techniques and equipment without unusual hazard.

COST AND DELIVERY SCHEDULES

If the program is launched immediately, the first plant can be ready to operate by the end of 1960. The first plant can be delivered within 22 months after orders are received. Subsequent plants can be delivered at the rate of 1 per month for the next 3 months, and 2 per month thereafter. Based on the sale of about 25 identical plants, the estimated cost per completed plant will be approximately $4 million. This cost includes reactor, turbine-generator, auxiliary equipment, and service buildings—all installed—as well as the first core fuelload and allowance for the cost of land and the cost of interest during construction. The cost will vary slightly to accommodate local site conditions and special features which may be added to satisfy local requirements.

Power plant data (estimated)

Power output:		
Gross electrical output (unity power factor)	KW	5,000
Reactor power	KW	21,800
Gross plant heat rate	BTU/KW-HR	14,800
Reactor data:		
Type		Boiling water
Cycle		Single, direct, saturated steam
Mode of reactor flow circulation		Natural convection
Steamflow	Lbs/hr	66,400
Reactor pressure	psig	650
Saturation temperature at 650 psig	°F	497
Core assembly:		
Core diameter (circumscribed circle)	in	50
Number of fuel bundle assemblies		44
Number of control rods		9
Fuel:		
Fuel material		Enriched UO_2
Total weight of U in reactor	lbs	4,021
Total weight of U–235 in reactor (initial load)	kg	45
Design Irradiation Level [1]	MWD/T	5,000
Initial Enrichment [1]	%	2.7
Refueling cycle [1]	Months	6
Unit assembly replacements/cycle [1]		12
Uranium thruput	lbs/yr	2,230
Zircaloy-2 thruput	lbs/yr	78

[1] Equilibrium cycle.

NUCLEAR METALS, INC.,
Concord, Mass., December 2, 1958.

Mr. JAMES T. RAMEY,
Executive Director, Joint Committee on Atomic Energy,
Congress of the United States, Washington, D. C.

DEAR MR. RAMEY: This is in reply to your letters of August 21 and October 30, 1958. I have read the proposed expanded civilian nuclear power program, but have not found the time to give it enough serious thought so that I can make significant comment. In general, the proposed program sounded good.

In connection with table 1, it occurred to me that it is rather ineffectual to specify reactors by mentioning the moderator and the coolant. It is well known that most of the difficulties associated with reactors are concerned with the performance of the fuel element. It would, therefore, seem to make sense that a reactor type should also contain a clear statement of the proposed fuel element which will enable the reactor to perform successfully. More attention to the type of fuel element rather than the moderator and coolant appears to be desirable.

Very truly yours,

NUCLEAR METALS, INC.
ALBERT R. KAUFMANN,
Vice President and Technical Director.

NUCLEAR PRODUCTS—ERCO,
DIVISION OF ACF INDUSTRIES, INC.,
Washington, D. C., October 23, 1958.

Mr. JAMES T. RAMEY,
Executive Director, Joint Committee on Atomic Energy,
Congress of the United States, Washington, D. C.

DEAR MR. RAMEY: In reply to your letter of August 21, it is my opinion that the Joint Committee print entitled "Proposed Expanded Civilian Nuclear Reactor Program," dated August 1958, represents a carefully considered and well-balanced program.

In reply to your specific questions, I desire to make the following comments:

1. I agree with the 3 major objectives in principle, but believe there is much more than a 2-year differential between competitive nuclear power in the United States and free world nations burdened by high cost conventional power. I would be inclined to set the date for these nations as 1965.

2. I am in agreement with the general technical objectives on page 5. I would suggest, however, analysis of safety requirements as an additional item. I am aware that AEC, the American Standards Association, and various national technical societies are working on this problem, but inasmuch as safeguard requirements result in a major item of capital cost, this could well be added to your catalog of important items of cost.

3. I am in agreement with the technological program described on pages 6 and 7.

4. Referring to the reactor listed in table I:

(*a*) "Process heat reactor" differs from the other reactors listed in that it describes a purpose rather than a type. I believe there are alternative choices of reactors that could prove most suitable for process heat and that at least two, and possibly more, reactor types should be included in this low-temperature category.

(*b*) It is not clear why a steam-cooled, heavy-water-moderated reactor is specified. It would appear to have the disadvantages of a very high-pressure coolant and risk of heavy water contamination, with no compensating advantages. Gas cooled would appear to be a broader category which could include steam if this appeared to offer any advantage.

(*c*) An intermediate energy breeder would appear to be a worthwhile project only if theoretical considerations indicated that breeding in the particular reactor is possible in the intermediate energy range under consideration.

(*d*) Reactors of large capacity will undoubtedly lead to lower actual power cost, and are justified if built by private capital with acceptance of long construction time and risk that the power cost may not prove economic. If the purpose is to demonstrate the capability of a reactor type to produce economic power, I believe this can be done much sooner and less

expensively in reactors of small or intermediate size. It is unlikely that more than 2 or 3 of the 9 reactors listed with power in excess of 100 microwatts will survive economically, and I believe the unsuccessful types can be eliminated much sooner if the size is drastically scaled down. Lessons learned with small successful reactors would lead to more rapid progress in developing large reactors of the same type. At least it is suggested that size per se be deemphasized and that large reactors of an early generation be built only if convincing arguments can be advanted to show that the important parameters of cost cannot be studied in small reactors.

5. I consider the cost estimates on page 8 reasonable.

6. In my opinion, the policies of the organization on page 9 are good, with the exception already noted that I believe AEC should not build large-scale demonstration plants unless it is clearly shown that the most important parameters such as power density (power per unit volume of core) cannot be duplicated in a small reactor of the proposed type.

7. The problem of third party liability in connection with foreign reactors and reactor components designed or built by United States companies remains a major obstacle to foreign business. Although indemnification by foreign customers and national states to United States manufacturers are a factor in meeting the problem, it is believed that international conventions of the general type envisaged and presently under study by the OEEC and Euratom offer a more appropriate remedy. Recent meetings between some members of United States industry and Euratom officials involving discussions on third party liability and a draft OEEC treaty, demonstrate clearly the rigorous efforts being made to meet this problem.

Since it is our understanding that participation by the United States in the Euratom program is to be on the basis of cooperation in lieu of direct participation as a member state, consideration should be given to the extent to which United States courts will recognize the provisions of foreign treaties, which it is anticipated will extinguish, or at least limit, the liability of the reactor supplier, in the event litigation based on a foreign incident is brought against United States companies directly in the United States. Indeed, it may be advisable to consider the possibility of legislation that would prohibit suit in this country for accidents arising from reactors abroad.

Sincerely yours,

H. ETHERINGTON, *Vice President.*

RAYTHEON MANUFACTURING CO.,
Waltham, Mass., November 6, 1958.

Mr. JAMES T. RAMEY,
Executive Director, Joint Committee on Atomic Energy,
Washington, D. C.

DEAR MR. RAMEY: In reply to your reminder of October 30 and letter of August 21, you may be assured of my substantial agreement with the objective of the proposed expanded civilian nuclear power program.

I have delayed replying in full with the hope that the AEC would have notified us with respect to their intended action on a proposal we submitted in August for an evaluation study of an advanced liquid metal reactor concept. Our continued participation in policy discussions and reactor engineering activities will depend upon acceptance of this proposal.

Sincerely.

T. H. JOHNSON, *Vice President.*

SYLVANIA-CORNING NUCLEAR CORP.,
Bayside, Long Island, N. Y., October 30, 1958.

JOINT COMMITTEE ON ATOMIC ENERGY,
Capitol Building, Washington, D. C.
(Attention: Mr. James T. Ramey, Executive Director.)

GENTLEMEN: Permit me first to thank you for the opportunity which you have afforded to us to comment on the Report on the Proposed Expanded Civilian Nuclear Power Program. As I pointed out in my testimony before the Joint Committee earlier this year, I agree fully on the need for a clear statement of the objectives of any such program and for the development of an integrated approach to meet these objectives. I therefore particularly welcome the

opportunity you have given us to study and comment upon the present proposals and would equally welcome any opportunity to participate in seminars which may be held on this subject in the future.

Turning to the report itself, the statement of the general objectives of the nuclear power program is clear and unobjectionable. I would only suggest that it would be worthwhile to state as an additional specific objective one which seems to be implicit throughout the rest of the report—namely, that, if the presently stated objectives are to have full force and impact, they must be achieved in a manner most consistent with the operation of our free enterprise system. I think that we would all agree that fundamental to the overall objective of the proposed program is a demonstration of the comparative virtures and strength of our free enterprise system over the controlled economics of communism. Accordingly, it would be a hollow achievement indeed if our attempts to achieve competitive nuclear power and to fortify the country's worldwide position of leadership in the peaceful applications of atomic energy were made at the expense of our free enterprise system.

We are certainly in full agreement with the general technical objectives set forth on pages 5 and 6 of the report. I would like to emphasize, as I have in the past, the need, in connection with cheaper components, for simplification and standardization, adoption of less stringent specifications and the elimination of technical elegance where not necessary for functionally adequate and same components and systems.

With respect to the estimated costs of the program. I am really in no position to say whether or not they are reasonable. Certainly, I cannot argue with the cost of $500 per kilowatt if that is to be the estimated cost of obtaining information necessary to substantially produce compercially competitive power. On the other hand, I would assume that the actual costs of producing nuclear power, to be competitive, will have to be reduced within the next 10 years to something below $300 per kilowatt of installed capacity of electrical and steam-generating equipment, and 10 mills per kilowatt-hour.

I am considerably more troubled by the suggestion of a list of specific reactors and the nature of the proposed organization and administration of the program. The nature of the proposals in this respect seem to be inconsistent with the objective of utilizing the free enterprise system to the maximum possible extent.

In the report, provision is made for the AEC to decide upon which specific reactor types ethe program would be concentrated. While an open end is provided for choice of additional types, the choice, in any event, would ultimately lie with the AEC. The desire of the committee and the Commission to limit the scope of the program to potentially feasible concepts within the limitation of funds available for the program is of course understandable. The desire to ascertain that an adequate number of reactors will be built is also understandable particularly in the background of some of the shortcomings in this respect of the current power-development program. However, I would submit that such shortcomings as the current program may have are due more to the lack of incentive provided for private industrial participation. Incentive, normally provided by potential profit resulting from market demand, is of course indispensable to the effective functioning of a free market. In the absence of current market demand in our industry, we may seek to achieve the proposed objectives of the power program in one of a number of alternative ways. Among these is the possibility that the Government might participate either directly, or through direct subsidization of private industry, in developing specific reactor types. Alternatively, the Government may seek to provide a substitute for market demand—in effect, create a market—to assure economic reward to the most efficient producers until such time as costs are reduced to the point at which normal market demand will take over. I submit that the latter technique is far more consistent with and better calculated to effectively utilize our free enterprise system than is any program based upon overall governmental direction or direct subsidization.

I would think that the ultimate objective of a limited number of economically feasible reactor types might better be achieved, consistent with all of the objectives of the program, by encouraging competitive bidding on the part of utility operators on reactor types of their own choice; to this end the Government might provide incentives in the form of tax relief or otherwise, for varying degrees of success in achieving predetermined cost and production goals. Such a program would have the advantage of permitting reactor types to be determined on the basis of natural selection by free competitive enterprise working toward the

traditional incentive of profit in the event of success and risking financial loss in the event of failure. Throughout our history, one of the most remarkable virtues of our free enterprise system has been its almost unerring ability to efficiently select by free competitive processes the best product most efficiently produced.

With the foregoing in mind, I proposed in my "202" testimony before the Joint Committee on February 26, 1958, a detailed program to accomplish these objectives. At that time, I proposed that a goal be established of 5 to 10 full-scale power reactors within 5 years, each to generate electric power at a cost of 15 mils per kilowatt-hour or less, and that an installed plant cost not to exceed $300 per electrical kilowatt. Consistent with the objective of utilizing our free enterprise system to the maximum extent possible. I suggested that such a program be conducted with a minimum of Government control and interference and with maximum utilization of the normal processes of our free enterprise system. I pointed out that this would preclude any a priori decisions on the part of the Government as to what types of reactors should be constructed, and by whom. The output and cost goals once set, I suggested that it be left to free competitive enterprise to select the types of reactors that might best meet these goals. I suggested that any combination of a reactor manufacturer and a utility group should be permitted to approach the Commission with a reactor proposal intended to meet the established goals. The type of reactor which the combination would propose would be of little consequence, subject only to certain minimum conditions and understandings:

1. It must obviously meet applicable health and safety criteria.
2. It must represent a type which could be successfully utilized by foreign nations which we wish to favorably influence.

It should be recognized in this respect that most foreign nations generally do not have an available supply of U–235. Therefore, reactors making use of highly enriched fuels may not be attractive to our foreign friends unless we are prepared to make U–235 available to them with a minimum of controls and restrictions and under the same conditions as those made available domestically. I gather from reading pages 11 and 12 of the report that it is contemplated that U–235 would be so made available to our foreign friends.

Finally, as I pointed out in my February testimony, successful participation by domestic private enterprise in such a program would require statutory provision of economic incentives for the achievement of the determined goals. By the same token, if such a program is to take advantage of the natural selective processes of the free enterprise system, participants must be expected to risk some part of their own funds if they fail to achieve the established goals. To achieve these ends, I proposed that suitable legislation be enacted to permit electric utilities either singly or in combination to receive rapid depreciation of no longer than 5 years on plants and facilities which the AEC authorized for participation in the program. I suggested that provision also be made for any additional tax incentives which would be necessary to make up the difference to participating utilities between the cost of conventional power and the 15 mils sought to be attained by the program. Additional incentive would thereby be provided automatically for the attainment of anything better than 15 mil power. Similar additional incentives might be specifically provided in connection with achieving a goal of installed cost of $300 per electrical kilowatt. The participating companies' own funds would automatically be at stake to the extent that the desired goals are not achieved.

I would like to make one final suggestion with respect to the composition of any future group which may study or discuss problems of this type. If the problem of competitive nuclear power and particularly the costs of the fuel cycle are to thoroughly explored, and all potentially effective avenues to solution investigated, I would suggest that it is desirable that fuel and component manufacturers, as well as companies interested in reprocessing, be represented in any groups which may study or discuss this problem, in addition to corporations interested principally in reactor design and construction.

In conclusion, I would like to compliment the Joint Committee, the Commission and the advisory group on the excellent job that all have done in presenting a proposal for further discussion and comment. Whatever may be our own views on the substance of the proposals or their ultimate disposition, these proposals constitute a major step forward in directing attention to the fundamental question of our nuclear power program and of how the objectives may best be achieved.

Respectfully yours,

LEE L. DAVENPORT.

WESTINGHOUSE ELECTRIC CORP.,
Pittsburgh, Pa., November 10, 1958.

Mr. JAMES T. RAMEY,
Executive Director, Joint Committee on Atomic Energy,
Congress of the United States, Washington, D. C.

DEAR MR. RAMEY: I am appreciative of the opportunity to comment on the proposed expanded civilian nuclear power program which was attached to your letters of August 21, 1958 to Mr. John W. Simpson and me. Mr. Simpson's thoughts are incorporated in my remarks.

The following comments refer specifically to the seven questions raised in your letter of August 21:

1. I concur with the three major objectives stated on page 4, although minor word changes could be considered for the purpose of clarification. I have rearranged the objectives in order of priority. My first objective would be:

(*a*) Fortify the position of leadership of the United States in the peaceful applications of atomic energy, particularly with regard to power. (The words "in the eyes of the world" have been omitted with the thoughts that the intrinsic worth of our technical leadership in the nuclear field is as important as external appearances.)

The remaining two objectives, while important, are to me quite secondary when compared with this country's leadership. I would suggest rewording these as follows:

(*b*) Achieve and demonstrate in the high fuel cost areas of the United States nuclear power competitive in cost per kilowatt-hour by 1970.

(*c*) Achieve and demonstrate in the still higher fuel cost free world nations nuclear power competitive in cost per kilowatt-hour in advance of 1970 and as soon as possible consistent with a sound but aggressive research and development effort.

2. The general technical objectives stated on page 5 are adequate if broadly interpreted to reflect the great amount of basic development work required in such fields as reactor physics and metallurgy. Also, I consider it highly important that the development programs which are carried out be tied to specific goals which relate directly to tangible reactor project objectives.

3. The technological program is well thought out and well stated. Its flexibility is important. At the same time, its success will depend upon the close integration of research and development with plant construction, as emphasized under 2 above.

4. I do not think that there is any "best list" of power reactors for this program. The list proposed in table I is more than adequate as the basis for developing a vigorous program and we must be careful not to spread ourselves too thin. The power ratings given are of questionable value at this time and must be determined as the orderly development of each reactor type proceeds.

5. The cost estimates appear to be reasonable.

6. Organization and administration of the program in the manner outlined is desirable over at least the next few years, but can only be achieved through adequate technical staffing of the Atomic Energy Commission. At the same time, this staff must function in a manner which will permit the full exploitation of the initiative of private enterprise. The program must be national rather than Government in character.

7. I am sure that as the program progresses there will develop needs for forms of assistance either not now contemplated or available under the Atomic Energy Act as now written. Certainly, the suggested revisions of sections 44 and 169 are highly desirable moves in the direction of permitting the maximum yet reasonable flexibility to the Atomic Energy Commission in its administration of the program.

I have publicly supoported the desirability of a national policy and program directed toward the leadership of the United States in nuclear power development and toward the achievement of economic atomic power. I am pleased that the Joint Committee has devoted the time and effort which it has to the formulation of a statement which I believe can be most helpful. I am sure that it is the intention of Congress that continued close cooperation of industry and Government and maximum use of our established business system will be the keystone of our nation's atomic power development program.

Sincerely,

CHARLES H. WEAVER, *Vice President.*

APPENDIX 2

REPLIES FROM REACTOR EXPERTS

(NOTE.—Page numbers and reference to tables, etc., in the following letters refer to the Joint Committee publication of August 1958, entitled, "Proposed Expanded Civilian Nuclear Power Program.")

GENERAL ELECTRIC CO.,
HANFORD ATOMIC PRODUCTS OPERATION,
Richland, Wash., October 24, 1958.

Mr. JAMES T. RAMEY,
Executive Director, Joint Committee on Atomic Energy,
Congress of the United States, Washington, D. C.

DEAR MR. RAMEY: This is a reply to your letter of August 21, 1958, in which you request my views and comments on the Joint Committee print entitled "Proposed Expanded Civilian Nuclear Reactor Program," dated August 1958. I welcome this opportunity to express my opinions on this most vital national problem, which is so admirably described in the program document.

At the outset I must express strong opposition to the two major innovations proposed by the new program. Here I refer to the two provisions which require that (1) reactors to be designed and constructed will be selected by the Commission on a project-by-project basis, and (2) Government-owned large-scale plants will be constructed where no "reasonable proposal" is received from industry. Item (1) greatly increases the extent of centralized program direction, and I submit that no centralized governmental organiaztion can properly assess the relative merits of various plant designs and make all the other major decisions that are such an essential part of our industrial process. Taken together, I do not see how these two new program features are going to stimulate construction of power reactors except by the Government. This, in my opinion, is the wrong path if there is any practical way to avoid it. Government construction is better than none only as a means of progressing technological development. It contributes very little to the demonstration of competitive economic power. In the interest of actually achieving and demonstrating economic nuclear power, as called for in the major program objective, I believe that we should limit Government-owned plants to small experimental and prototype reactors, and, of course, production reactors. Naturally, the fact remains that, if acceleration is needed (and I agree that it is), we must find a way to achieve it. During the past year, in meetings and correspondence with both the AEC and the Joint Committee, I have advocated a Federal subsidy as the best way to stimulate the progress of nuclear power, and, with the passage of time, I am more convinced than ever that this is the right approach. The general argument is summarized by the following quotation from my letter to the Honorable Carl T. Durham of December 16, 1957:

"It is my conviction, as I said during the committee's seminar, that the vigorous and full-scale participation of industry is essential to the progressing of the Nation's nuclear power program. Unfortunately, nuclear power today is a long way from being economic. I am convinced that several generations of any reactor type will have to be built and operated, and this operation supported by an extensive research and development effort, before these nuclear plants could compete with the capital-cost range of large conventional stations. This conclusion is strongly supported by the cost-performance history of the Hanford plant.

"If it is accepted that our national interests, particularly in the international area, demand that the industry development go forward at a rapid pace, then the economic realities say that some form of Government support is required, for private industry alone cannot provide all of the money needed for such a program. In my opinion, the best type of support, and the one which will yield the maximum returns for the taxpayers' investment, is a Federal subsidy designed to properly stimulate the industry's growth. In establishing the form of subsidy, an overriding consideration is that the Government should not promote any reactor type or fuel cycle. In other words, industry should have maximum freedom to make its own economic decisions, and the most important of these are the technical ones.

"The only alternative to a subsidy would be Government construction and ownership of at least the reactor portions of the plants. This approach would take the program outside of the competitive-enterprise system; it could not be developed under the risk-and-profit sanctions and stimuli which, in the final

analysis, determine when a plant or business is competitive. These factors cannot be simulated under Government ownership. Yet the selection of plant types, sizes, locations, and methods of operation, all critical steps in the normal business process, are vitally dependent upon the risk-profit relationship.

"Additionally, of course, under a Government-ownership system the costs to the taxpayer would be greater than in the case of a proper subsidy. Both in terms of first-cost outlay and in the time and cost to achieve competitively produced nuclear power, the subsidy route is in the taxpayers' interests.

"It is essential, of course, that the Nation's program provide for continued strong support by the Government of research and development work in this field. On the other hand, we must not forget that research and development alone will only point the way and will prove nothing. Technology alone cannot be used to decide what is a good business risk."

The Federal subsidy might take the form of (*a*) a capital subsidy, (*b*) a subsidy through plutonium buyback, or (*c*) both. We quickly conclude that subsidy through plutonium buyback prices is, all things considered, undesirable principally because of the unwanted effect this would have on the trend of reactor technology and development. A few months ago the Honorable Clinton P. Anderson outlined a capital-subsidy proposal in an address before the Nuclear Energy Writers Association in New York City (June 18, 1958). This outline contains the major features of an adequate capital-subsidy program but, of course, many details remain to be worked out. In my opinion, the amount of grant should be less than the quoted 90 percent of the estimated cost difference between the nuclear plant and the conventional plant; in fact, the grant might best be expressed in terms of a flat number of dollars per installed kilowatt for a given plant size, which sum would decrease somewhat from year to year as technology progresses. That is, this grant should be small enough and defined so that any nuclear plant undertaking will involve a real element of risk and so that a positive incentive is provided for industry to select the most promising reactor types.

With the above background, I should now like to comment on the specific questions posed in your letter.

1. The establishment of objectives is the most important step of all. If we accept the three major objectives given on page 4, or any other set of objectives, the program that follows must be one that has a good chance of meeting these objectives. I do not believe that the program outlined in the staff paper will "achieve and demonstrate in the United States nuclear power competitive in cost per kilowatt-hour by 1970," as is called for in major objective (*a*). A further comment: Because of the major importance of objectives in any program I prefer to see them spelled out with a great deal more precision than is used on page 4.

2. I have no serious objection to the listing of technical objectives given on pages 5 and 6, although the principal theme presented here is that all major elements of cost must be reduced. Some of the items listed are much more important than others. For example, breeding per se is of no importance to the development of economic nuclear power at an early date. However, the subject does deserve a certain amount of research and development attention because it is an interesting and appealing technical problem. Research in this field might eventually lead to something of economic value many, many years from now.

3. See above and item 4, below.

4. In my opinion, Government-owned reactors should be limited to small experimental and prototype reactors and, of course, production reactors. All true power reactors should be selected by industry groups who are willing to risk money under a capital-subsidy program with this program designed to maximize competition. Reactor types to be built would then be determined by competitive forces within the industry and not by centralized direction. I believe it is going to be necessary to concentrate on very few reactor types if we are ultimately to achieve competitive power costs and at the same time keep the overall cost of the Nation's program within reasonable bounds. Certainly, there is no need to incur the cost of building all types of full-scale plants at Government expense. In fact, continued design and construction activity on all conceivable types of power reactors will most likely hinder rather than help the attainment of competitive costs. A capital-subsidy program could stimulate this selection process, for it could be designed to encourage the building of the most promising types, and the building

of the least promising types would be limited by the extent to which industry chooses to take the risk. In the meantime, the Government program of research and development, which would include small experimental and prototype reactors must continue and would cover almost all classes of power reactors, including, to some extent, those which have the least promise. Industry should, of course, be consulted before decisions are made concerning reactor experiment and protoype construction by the Government.

5. The cost estimates appear to be reasonable.

6. I do not agree with the policies of organization and administration proposed on page 9. As already stated, I do not agree that the program of centralized direction and Government construction of full-scale power reactors is the best way to advance nuclear-power programs in this country. Incidentally, I assume that the dismantling and sale provisions outlined on page 11 are not really intended to apply to the Hanford-type (production) reactor listed in table I.

7. This question has been answered in the early part of this letter. I repeat that a capital-subsidy program, coupled with continued strong support by the Government of research and development work in this field, is the best way to stimulate the progress of the Nation's nuclear-power program.

The above statements represent my personal opinion, based on my own experience in this field. They do not necessarily reflect the experience of other parts of the General Electric Co.

Sincerely yours,

A. B. GRENINGER,
Acting General Manager.

ARGONNE NATIONAL LABORATORY,
Lemont, Ill., November 21, 1958.

Mr. JAMES T. RAMEY,
Executive Director, Joint Committee on Atomic Energy,
Capitol Building, Washington, D. C.

DEAR MR. RAMEY: My apologies for not having replied earlier to your request for comments on the Joint Committee's reactor program. As you know, the South American tour and Geneva Conference, with the European tour following it have kept me away from the Laboratory most of the time since last May.

As far as the JCAE reactor program is concerned, I find myself in general agreement. Personally, I strongly approve of any move which will transfer to industry the responsibility for the development of well-proven reactor types, since I firmly believe that industry is better equipped to do this kind of work than is a purely scientific and technical laboratory, and most of the Commission installations are essentially just this. I believe that the Commission should give industry whatever support turns out to be needed to accomplish this continued development in an effective manner. In some instances it may mean that the Commission and its laboratories will have to undertake things that theoretically industry should do for themselves but the responsibility should be kept on industry's shoulders.

As you know, I feel quite strongly that in the longer view major effort and high priority should be placed on the breeding program. At least as far as the fast breeder is concerned, I personally believe the prospect for success is good. Over the long pull, nuclear fuels will make a really major contribution to the world's energy requirements only if breeding is successfully accomplished.

I would like to stress one other matter. I personally believe that the use of nuclear fuels and reactors for the production of electrical energy may not, in the long run, provide the major contribution which nuclear fission can bring to mankind. Potentially, reactors can uniquely supply ultra-high temperatures and tremendous radiation fluxes and these may possibly be of greater significance than their fuel equivalent in electrical energy. Obviously, if we knew with certainty what the potentialities in this area were and how reactors which would achieve the conditions required to fulfill these potentials could be built, we should be heavily engaged in this area immediately. Clearly these are things we do not know. Necessary materials of construction to provide ultra-high temperature operation are not available. Basic understanding of the interaction of radiation fluxes with matter are not fully understood. Clearly major "projects" in this area are not warranted and consequently, the importance of studying these areas is likely to be overlooked. I would simply like to bring to the Joint

Committee's attention that basic research and development in these areas must not be lost sight of due to the pressure for obtaining economic electrical power from nuclear fuels. A considerable and continuing effort must be placed on problems which fall in this long-range area, so that the United States may be assured that its interests in this field are being vigorously prosecuted. Otherwise we could well find that we have provided the world with an additional and needed energy source but that other countries, who can do this sort of research as well as we, will have developed, and perhaps control, the unique contributions which nuclear fission may prove able to provide.

Sincerely yours,

NORMAN HILBERRY, *Director.*

INTERNUCLEAR CO.,
Clayton, Mo., October 31, 1958.

Mr. JAMES T. RAMEY,
Executive Director, Joint Committee on Atomic Energy,
Congress of United States, Washington, D. C.

DEAR JIM: This is in response to your letter of August 21, 1958, regarding your "proposed expanded civilian nuclear reactor program."

As to the three stated objectives on page 4, it seems to me that at this time there is really only one and that this one stands out as being of primary importance to the United States. I am referring to the third one, which is to "fortify the position of leadership in the United States in the eyes of the world in the peaceful applications of atomic energy, particularly with regard to power."

The more fully this objective is realized, the more quickly competitive power will be achieved and demonstrated. To set the targets of 1970 at home and 1968 abroad appears to me to be purely arbitrary and simply clutters the picture by inviting questions as to why these particular years and whether, after all, competitive power here at home is really so important anytime in the near future in view of our plentiful supply of fossil fuels.

Putting it differently, the importance of item (*c*) can be clearly demonstrated as an essential part of American foreign policy, whereas the importance of item (*a*) cannot be so clearly demonstrated on domestic grounds alone. Item (*b*) adds little except for the arbitrary date of 1968 which, as I have already indicated, tends to raise questions rather than to help establish a clear-cut policy.

I recognize, of course, that there will be many conflicting views as to how best to fortify our position of world leadership, but so long as the main policy objective is clear, a continual review of the best methods for its accomplishment is essential.

The general technical objectives and the technological program as stated on pages 5 and 6 seem excellent to me.

As to table I, we offer two comments. First, we hope that the "organic-cooled reactor" includes the concept of a reactor which is moderated with heavy water. Second, we have studied in some detail the concept of an automatic boiling column reactor, and we believe that this should be included in the list.

The cost estimates on page 8 seem quite reasonable to us, and the policies on organization and administration which are proposed on page 9 seem quite adequate.

In the section beginning on page 11 entitled "Assistance to Projects in Other Countries," it would be well to include under item (b) some assurances on the price of enriched uranium as well as its availability over the amortizable life of the reactor.

Finally, I notice at several points in the document that reference is made to invitations which are to be sent to private organizations for various projects and that the AEC shall set realistic dates for submission, approval, and the negotiation of proposals. It occurs to me that there may be some differences of opinion regarding what is reasonable, and although it is pointed out on page 11 that the AEC would assume responsibility for determining what is reasonable, it would nevertheless be well for the AEC to make certain that it has competent advice from industrial circles on what may be considered reasonable. This would tend to avoid the danger of AEC undertaking projects when private capability exists just because of a miscalculation on the amount of time required for the private organization to submit its proposals.

It is a privilege to be able to present these views and comments, and if we can be of any further possible service, please call upon us.

Sincerely yours,

PHILIP N. POWERS, *President.*

WESTINGHOUSE ELECTRIC CORP.,
BETTIS ATOMIC POWER DIVISION,
Pittsburgh, Pa., November 11, 1958.

Mr. JAMES T. RAMEY,
Executive Director, Joint Committee on Atomic Energy,
Washington, D. C.

DEAR MR. RAMEY: As you noted in Mr. C. H. Weaver's letter of November 10, my comments on the proposed expanded civilian nuclear power program are incorporated into his remarks.

Sincerely,

J. W. SIMPSON,
Vice President and General Manager.

1025 CONNECTICUT AVENUE NW.,
Washington, D. C., November 14, 1958.

Mr. JAMES T. RAMEY,
Executive Director, Joint Committee on Atomic Energy,
Washington, D. C.

DEAR MR. RAMEY: Thank you for your letter of August 21 requesting, on behalf of Congressman Durham and Senator Anderson, my views and comments on the Joint Committee print entitled "Proposed Expanded Civilian Nuclear Reactor Program." I welcome this opportunity to present a few comments which are prompted by your letter.

With regard to the program objectives, the target dates selected will have an important influence on the nature of the developmental programs. Considering first objective (*b*), I assume that the target date of 1968 for achieving economic nuclear power in high-cost free world nations is based upon the best judgments of representatives of these nations. In the case of objective (*a*), there appears to be little in the economic and conventional fuel resources picture in this country to warrant the urgency implied by a target date of 1970. It is apparent that the situations existing in Western European countries and in the United States are quite different, and it seems hard to believe that if the situation abroad requires a target date of 1968, that the situation in the United States would change to such an extent as to warrant a target date only 2 years later. Moreover, in the light of the differential in production costs of conventional plants in Europe and the United States, 2 years is a relatively short interval in relation to the time required for substantial improvements in the economic performance of nuclear powerplants.

I find it difficult to discern a logical basis for estimating the costs of a reactor development program to meet the specific objectives. If the objectives are considered of vital importance, then the cost of the program must be open ended. Conversely, if the availability of funds is limiting, then the objectives must lack firmness.

The most effective program to meet objectives (*a*) and (*b*) may not be consistent with that to meet objective (*c*), particularly if the availability of funds is limiting. For example, if objectives (*a*) and (*b*) as stated are of primary national importance, then it is conceivable that the most effective use of funds would be to concentrate development on 1 or 2 basic reactor types. One does not require a whole catalog of reactors to meet these objectives. On the other hand, if objective (*c*) is overriding, then a broad technological program is indicated. It would appear, therefore, that some statement of priority would be needed in the interest of guiding those responsible for formulating implementing programs.

If the objectives are considered as a mechanism for bolstering and maintaining an extensive United States nuclear industry, then a major question arises. As evidenced by the recent awards of contracts for nuclear powerplants, the United States industry seems to be capable of competing in foreign markets without Government assistance. I am told that estimated costs for production of electricity by the nuclear powerplant recently awarded to a United States firm by the SENN group in Italy are only 5 to 10 percent above the competitive level in that area, and that there is reason to believe that when the plant is operational, increased generating capacity over the design capacity can be realized, which will make production costs competitive. On the other hand, it appears to be generally accepted by representatives of the nuclear industry in this country that the benefits of potential export markets will be short lived. Foreign industry will not take long to develop the know-how and skills which represent our

immediate advantage, and their long-term advantage is their ability to manufacture at lower costs in addition to making no monetary demands in the area of foreign exchange. Under these circumstances, one may question why the Government should attempt to underwrite an extensive nuclear industry in this country. Could not this money, even though the "cost is relatively small compared to other Government expenditures," be more effectively used in the national interest in some other direction, for example, in relieving the school situation?

The general technical objectives as stated in the committee print are sufficiently broad and all-inclusive to cover an adequate research and development program. The type and scope of the reactor construction program, however, could depend, as mentioned above, in large part upon the answers to the questions raised in the preceding paragraphs. There appears to be a feeling among nuclear powerplant manufacturers that the objective of competitive nuclear power in the high-cost free world nations is close to realization on the basis of current technology.

The job of effectively meeting program objectives, no matter what they are, is essentially a technical and engineering one, though there will be honest differences of opinion even among technical experts as to the details of the program. In any case, I believe that the program should remain flexible, rather than to attempt to pin down a developmental schedule of reactor types and capacities at this time. I am wholeheartedly in favor of the policy as firmly stated in the committee print that positive leadership must be supplied by the AEC. In the last analysis, this leadership must emanate from the office of the Director of Reactor Development and his staff.

The question of providing an atmosphere in which positive leadership can flourish brings up a matter which is of increasing concern to me. I believe that it is important for those responsible for programs to obtain comments and views from interested organizations and knowledgeable individuals with regard to these matters. However, I am seriously concerned lest a procedure which has gained in popularity in the last year or two, of determining national objectives, policies, and technical programs by ad hoc committees, conferences of industrial and other representatives, magazine polls, etc., become a substitute for considered planning and judgments by competent individuals who have the responsibility for implementing the national objectives. The procedure is, I believe, symptomatic of a lack of strong leadership, and conversely, this procedure discourages the emergency of strong leadership.

The glamour and unrestrained optimism associated with the potentialities of nuclear power have been to a large extent displaced by more realistic attitudes in this country and abroad. However, in this country, since economic considerations are not paramount, certain elements of a nontechnical nature—foreign policy, public versus private power, and large investments, particularly by the equipment manufacturers—still play major roles in the decisions and policies which determine the inherently technical program of nuclear power development. Under the circumstances, it is easy to understand not only the difficulties involved in arriving at a program that will please everyone, but also the problems associated with planning and directing a well-coordinated technical effort. During the last 4 years the nuclear power program has suffered much from the pulling and hauling by conflicting interests represented in the three elements mentioned above.

Once the national objectives and policies have been established, say for a 5- to 10-year period, the AEC should assume the technological leadership for determining a program within that framework. This sounds simple and straightforward, but it clearly has not worked in practice. In addition to the aforementioned disrupting elements, the Reactor Development Division does not have sufficient administrative funds to attract the required numbers of competent technical individuals who, in addition to handling an ever-increasing administrative load, must also have time to think and to plan an effective program. Adequate remuneration for top positions is important, but I believe not the determining factor. To attract and keep competent leadership, the positions must also provide the authority needed to implement decisions. When opportunities for end runs around the Reactor Development Division are frequently provided, this in effect emasculates the authority and leadership which is so highly desired.

In view of the above, I believe it would be desirable for the Joint Committee to include in any proposed reactor development program strong positive support for a policy which will insure that the Reactor Development Division has the au-

thority, the staffing, and adequate administrative funds in order to effectively carry out its role.

In conclusion, and bearing in mind the real difficulties which are inherent in the Government's program under current practices, may I offer for your consideration the following proposal, prompted by the above discussion of the proposed expanded program for civilian nuclear power. In the light of information which has accrued during the last year or two, I wonder whether it would not now be feasible to make a fairly sharp break between the extent of the Government's program in this field and the activities of private enterprise. Three major considerations lead me to this suggestion. First, the generally successful approach illustrated by the AEC's 5-year reactor development program; particularly significant was the demonstration that such a wholly Government-supported program can be planned and administered with wide support among all interested parties and, except in instances where serious technical difficulties arise, meet target dates. Second, the fact that a number of industrial firms now have well staffed, extensive nuclear research and development facilities. Third, the demonstration by equipment manufacturers of their interest and aggressiveness in picking up promising nuclear powerplant types—for example, the boiling water and organic cooled reactors—and their willingness to make firm proposals for construction as well as to provide extensive performance guaranties without Government assistance.

On the basis of these encouraging developments and in the interest of establishing a manageable program for the AEC and of disentangling that agency from disruptive forces, I propose that the AEC's program be limited to the construction of experimental and prototype reactors required to demonstrate technical feasibility and provide economic information on new types of reactor designs. Under this proposal the construction of commercial-size units would be entirely the responsibility of industry. Objective (*b*) of the proposed expanded program can, I believe, be achieved by normal economic and competitive motivations both abroad and in the United States nuclear industry, together with the big assist to be provided by the joint United States-Euratom program. If the target date of objective (*a*) is extended so as to bear some relationship to this country's needs for nuclear power, I now believe that this also will be met under the influence of normal industrial incentives.

The above proposal will be construed in many quarters as evidence of support of the position of private utilities with regard to the Government's role in the development of civilian nuclear power. However, as the Joint Committee knows, I have always maintained an impartial position with regard to the public versus private power controversy, and I continue to do so. My recommendation is based solely on a desire to assist the Joint Committee in the formulation of objectives and policies for the development of nuclear power which will be consistent with the overall national interest and which will provide an atmosphre in which Government and industry can make rapid progress in close cooperation. The developments in the technical field and the activities of industry during the past year or two encourage me to believe that this now would be possible without the injection of conflicting interests.

I again thank you for providing me with this opportunity to present my comments. I will of course be happy to answer any questions Congressman Durham and Senator Anderson may have.

Sincerely yours,

GEORGE L. WEIL.

COMMENTS ON PROPOSED EXPANDED CIVILIAN NUCLEAR POWER PROGRAM

Alvin M. Weinberg, Director, Oak Ridge National Laboratory

GENERAL OBSERVATIONS

I greatly appreciate the opportunity to comment on the proposed expanded civilian nuclear power program. I am in sympathy with much of the proposed program; however, in one crucial respect—the relative emphasis placed on breeding—I find the proposed program seriously deficient. To list breeding as a general technical objective, having by implication no greater importance than, say, "cheaper field assembly of components" or "cheaper waste processing and disposal," is in my opinion a serious error. I would therefore urge very strongly that a fourth *program* objective be listed as:

(*d*) To develop power breeder reactors with low doubling time which will produce electricity at competitive cost by about 1975.

My reasons for urging the elevation of economical breeding to the position of a national objective rather than simply leaving it as one of many technical objectives have been stated in an editorial in the September 1958 issue of Nucleonics; I enclose this document as appendix I. Since the editorial was published, we have made good progress at ORNL on a study directed at reevaluating the importance of breeding in the national nuclear energy program. We find that breeding will very possibly become a necessity in about 40 years; and that in view of the estimated 20-year development time and 30-year service life of breeder reactors, vigorous development of breeders is timely. Our study stresses again the importance of short doubling time if our nuclear resources are to keep pace with our expanding economy. This requirement of short doubling time, and therefore high specific power ratings, justifies continued investigation of fluid fuel breeders, even though the difficulties of this type are great.

My other major criticism of the program is that for any given reactor type, the program does not seem to envisage a definite and orderly sequence of development which would clearly culminate, if successful, in the achievement of the program objectives. The proposed sequence of development is mainly one of increasing size—the implication is that economic power will be achieved simply by building reactors of increasing size. Although this may be true for reactors whose primary economic problem is high capital cost (one way to lower capital cost is to build the reactor larger), it is not true for many American types in which capital costs are relatively low. In these types, such as BWR, it is the fuel cycle cost which is high and the real issue here, as with most American reactors, is to lower the fuel cycle cost. In other words, I would find the sequence of proposed reactors more convincing if each proposed step were accompanied by a definite proposal for improving the fuel element or if, by implication, more of the money were devoted to the matter of devising better fuel elements.

To generalize this point of view, the whole program would be sharpened if, for each major reactor type, i. e., for each moderator, an orderly set of technical objectives were set forth, the achievement of which could be expected to lead to economic power. The general technical objectives are a catchall: some of the objectives, such as "cheaper field assembly," are of great importance for reactors like Calder Hall which are very expensive to erect; others, such as "better fuel elements," are particularly crucial for reactors which operate with expensive fuel elements. Would it not be better, after having stated the general technical objectives, to indicate for each line of reactor development which technical objectives are to be achieved and by what means? Such an analysis would show that for some reactor types the achievement of cheap nuclear power doesn't depend centrally upon building more reactors; rather, it requires developing fuel elements which will give adequate burnup and using them in existing reactors. In fact, should such fuel elements be found, many of the types will be reasonably economical; if such fuel elements cannot be found, none of the systems will be economical.

THE TAXONOMY OF REACTORS

The most difficult problem of reactor development is to settle on the reactor types which will be pushed wholeheartedly. As a first step it is helpful to group the various types according to some underlying principles—to devise a "taxonomy of reactors." I therefore propose such a taxonomy which I hope will help to clarify the underlying issues, and which could be incorporated in the final program.

There are many characteristics according to which one can classify reactors—that is, construct a reactor taxonomy. Some of these criteria are as follows:

(*a*) Neutron economy—that is, fraction of raw material which can be burned in the reactor system.

(*b*) Material efficiency or specific power—that is, the amount of power which can be extracted from a given amount of fuel.

(*c*) Thermal efficiency.

(*d*) Capital cost of system.

(*e*) Coolant or other engineering feature.

(*f*) Enrichment of fuel in reactor.

(*g*) Moderator.

The classification scheme which one chooses depends on whether one considers nuclear energy from the short-term standpoint or from the long-term

standpoint. From the short-term standpoint, the merit of a nuclear system is judged solely by economics—that nuclear system is best which, *in the short run*, minimizes the mills per kilowatt-hour. On this view, the long-term raw material situation is deemed to be unimportant. From the long-term standpoint, the raw material situation is dominant—those reactor systems are best which utilize the raw material most efficiently.

My own opinion is that the short-term future of nuclear energy in the United States is not of crucial importance; on a strictly economic basis we can do without nuclear power for a long time. On the other hand, the long-term future of nuclear energy as a major energy source is extremely important. I am therefore inclined to view reactors primarily in terms of their long-term prospects.

From this standpoint, the first three classifications are the most important: Neutron economy, material efficiency, thermal efficiency. The first is important because it determines what fraction of the raw material can be utilized; the second because it determines how large a nuclear economy can be supported at any one time; the third because it determines ultimately how much electricity can be extracted from the raw material.

To be sure, good figures of merit on each of these criteria result in lower cost power; however, other criteria such as capital cost also bear importantly on power cost. Nevertheless, from the long-term standpoint, where raw material utilization is controlling, neutron economy, or material efficiency, or thermal efficiency are more important than capital cost.

Since, to simplify the classification, we must choose only one criterion, I somewhat arbitrarily pick (*a*), neutron economy. According to this view the basic classifications are (*a*) reactors with very high raw material utilization (breeders), and (*b*) reactors with low raw material utilization (burners). I arbitrarily take "low" to mean less than 3 percent of the fertile material. There is, of course, a continuum of reactors whose conversion ratio lies between that of the true breeders and the burners. These are the "near breeders." However, the major technical paths have tended to separate reactors into types which breed and those which burn not more than 2 or 3 percent of the fertile material; for simplicity, I shall consider only these types.

A good case could be made for classifying reactor systems according to their material efficiency—that is, according to their specific power in kilowatts of electricity per kilogram of fissionable material held up in the whole system of the reactor plus chemical plant. Unless this number is high, our currently estimated reserves cannot sustain a really large nuclear energy system. Although I do not choose this as my primary classification, I have indicated what the material efficiency is in some of the most important cases discussed below.

According to the above principles of classification, in which neutron economy dominates, the two primary reactor kingdoms or "Phyla" are:

Phylum I. High utilization (breeders).

Phylum II. Low utilization (burners, utilizing not more than 2 to 3 percent of the raw material).

Among the high utilization systems are those based on the U–Th cycle, and those based on the U–Pu cycle. Among the low utilization systems are those based on highly enriched uranium and those based on slightly enriched or unenriched uranium. Thus the overall outline of the taxonomy is as follows:

Phylum I. High utilization reactors (breeders):

Class A. Thorium system breeders.

Class B. Uranium system breeders.

Phylum II. Low utilization reactors (burners):

Class A. Highly enriched fuel burners.

Class B. Slightly enriched fuel burners.

The taxonomy is repeated in greater detail on pages 12 and 13.

In the following pages I shall fill in the details of this classification scheme, and shall indicate where the reactors contained in the proposed program[1] fit. I also include incidental comments on each system.

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[1] For simplicity I have assigned a number to each reactor in the two tables (pp. 16 and 17 of the proposal); thus, II–10 is the 10th reactor in table II. The tables are reproduced on pp. 38 and 39.

Phylum I. High utilization (breeders).

Class A. Thorium system breeders.—I realize that there is a view current within the Commission that thorium breeding is intrinsically of little interest to the United States because of the limitation of the thorium supply. In my opinion this position is not a tenable one. In the first place, even with the demonstrated reserves of thorium, the energy content of the American thorium reserve at 50 cents per million British thermal units is worth 12×10^{10}. In the second place, the thorium picture throughout the world is by no means a discouraging one; it is shortsighted to assume that because we have not looked very hard for thorium in this country thorium will always remain scarce relative to uranium. Finally, the fact that thorium on the average is about 3 to 4 times as abundant as uranium means that in the extremely long-range view it is thorium which is the major raw material—not uranium.

Family 1. Aqueous homogeneous, thermal breeders:

Species a: Two-region, solution-slurry systems. Specific embodiments include (1) the HRE–3 which does not appear in the program. The omission of HRE–3 I consider to be a mistake, assuming that the present difficulties in HRE–2 can be overcome; and (2) large two-region aqueous homogeneous (75 to 150 MWE, I–5, 1965) which certainly should be undertaken if the previous item is successful.

Species b: One-region slurry. This is embodied in the PAR slurry reactor (II–10, 70 to 150 MWE, 1964). I include this here, even though it is a near breeder, not a true breeder, since its technology is so close to the breeder technology. I believe that a small prototype or reactor experiment of this type would be necessary prior to doing PAR.

Family 2. Fast and intermediate thorium system:

Species a: I presume that items I–19 (sodium-cooled fast or intermediate), as well as I–9 (intermediate energy neutron breeder), are fast or intermediate thorium breeders. Because of the low value of eta in the U^{233} system, and the low specific power of such reactors, it is quite unclear what advantage this system has.

Family 3. Heterogeneous thorium breeders: D_2O, BeO, or graphite moderated, gas cooled. Our studies indicate that such systems will have a marginal breeding gain, at best. In any case, their doubling time will be very long. I believe the present groups studying gas cooling will pursue these systems in the course of their regular studies.

Family 4. Fused salt and LMFR: I place these two together without specifying particular embodiments since the outlook for breeding with either of them is rather marginal and, from the engineering standpoint, they are very closely related. I will, however, return to these reactors—as burners—in a later classification.

Class B. Uranium system breeders.—

Family 1. Solid Fuel Breeders:

Species a: Sodium-cooled fast breeder, PRDC, 100 MWE (II–6, 1960).

Species b: Sodium-cooled fast breeder, ANL, 20 MWE (II–7, 1960).

In my opinion the fast breeder represents an extraordinarily difficult type of reactor—possibly more difficult than the liquid systems. In some ways it has always seemed unfortunate that the 100 mw. PRDC reactor went ahead before the ANL 20 MWE reactor had been finished. The central questions of the fast breeder—long burnup and higher specific power—look like very difficult, if not insolvable, problems. It is for this reason that I consider it a mistake to focus the greatest bulk of the breeder effort on the U–Pu cycle fast breeder, as is now being done at the expense of the basically simpler thermal U^{233}–Th cycle breeder.

Family 2. Fluid fast breeder: This could be very important, but needs an invention. I suggest continued basic work in this field.

Phylum II. Low utilization burners (use less than about 3 percent of fertile material)

There are two different classes, those which use fuel at high enrichment and those which use it at low enrichment. However, since both types utilize only a small fraction of the fertile material—in the one case the unused fuel appears in diffusion plant tails; in the other case it appears in radiochemical waste tanks—the fact that these two families are essentially members of the same phylum does not seem to be generally appreciated. Since the systems which use high enrichment must operate with low fuel processing cost, and preferably high

thermal efficiency, in order to make up for the high burnup cost, the most attractive high enrichment possibilities are the high-temperature liquid systems. I therefore consider in this class three types:

Class A. Highly enriched fuel burners.—

Family 1. Liquid fuel burners:

Species a: Fused salts (I–7, 10 MWE, 1964). This system combines high temperature and low reprocessing costs. It therefore can achieve, in principle, 2 mills per kilowatt-hour fuel cycle cost. I am very enthusiastic about this type and believe that if the engineering problems can be solved, it could become the basis for a large power economy. However, it does suffer from fairly poor material efficiency.

Species b: Liquid bismuth (I–14, 1964) and (I–20, 50 MWE, 1968). This system and the fused salt are in competition. I do not believe that both should be pursued to large scale; a choice should be made between them. My own predilection is for the fused salt, but the choice between the two is a difficult one.

Species c: Aqueous homogeneous burner. This system, as a straight burner, has too low efficiency to be competitive with a or b. On the other hand, it is further developed than the others; it also has the advantage of very high specific power.

The systems operating with highly enriched U, on the whole, are less sensitive to increase in raw materials cost than are those operating with unenriched uranium. For example, we estimate that if natural U feed goes from $10 to $50 (increase by a factor of 5) the cost of pure U^{235} increases by a factor of only about 2, assuming that power costs do not increase also. This may turn out to be an advantage of the systems which rely most heavily on diffusion plants for their feed.

Family 2. Solid fuel burners: Unless burnups of the order of 50 percent, at very high thermal efficiency, and with a simple reprocessable fuel are achievable, these systems do not appear attractive. The possibility of achieving these three requirements does not look good; this is the basic reason for going to the slightly enriched, high burnup, oxide systems.

Class B. Slightly enriched or unenriched reactors.—This class embodies most of the United States, and the world's, civilian power reactors. The families are best characterized by moderator, with coolant as a secondary characterization. Broadly, there are two families—the poor moderator systems (H_2O, organic) and the good moderator systems (D_2O, C, Be). The essential difference between the systems is the neutron economy and therefore the relative importance of fuel cycle and capital costs.

Subclass B'. Relatively poor neutron economy.—

Family 1. Proton moderated: Since hydrogen absorbs neutrons, hydrogen-moderated system have a basically poor neutron economy, and therefore the fuel cycle cost is intrinsically high. This is mitigated by lower capital costs, although even the most optimistic estimates place the capital costs of these reactors higher than for coal stations. Thus unless the fuel costs can be reduced below that of cheap coal, this type cannot achieve a truly competitive position with respect to coal.

In the long run it is the operating—i. e., the fuel cycle costs—which is most important. This has been true in conventional power technology and should be even truer in nuclear technology. *It must therefore be realized that by centering our United States development on poor neutron economy systems, we are in danger of always being at an essential disadvantage. In this respect the high-temperature liquid fuel (which mitigates this disadvantage of poor neutron economy and low material efficiency by very high thermal efficiency) and the good neutron economy D_2O-moderated systems have an essential advantage over the types upon which most of the United States effort is based.*

Subfamily 1'. H_2O moderated:

Species a: H_2O cooled (PWR type). These are embodied in II–2, Consolidated Edison (163 MWE); II–3, Yankee Atomic (134 MWE); and I–11, the pressurized water (200 MWE). In my opinion, it is not clear why I–11, which I interpret to be a large PWR, should be built until and unless longer burnup, cheaper fuel elements are achieved.

Species b: Boiling water cooled (BWR type). There are six embodiments proposed: II–1, Commonwealth Edison (180 MWE); II–4, Elk River (16.5 MWE); II–5, Northern States (50 MWE); II–14, Ptcific Gas & Electric (60 MWE); I–12, boiling water (200 MWE), and I–3, boiling water (10 to 50 MWE with nuclear superheat). As far as I can see, only I–3, with superheat, represents a fundamental advance in technology. The only technical objectives which pre-

sumably will be gained by building II–5, II–14, I–12 are connected with cheaper components and assembly. Again, the central issue remains the fuel element and its burnup.

Subfamily 1''. Organic-moderated: This system exchanges the problem of high pressure for the problem of handling organics under radiation. It shares with other proton-moderated systems the disadvantage of poor neutron economy.

Species a: Organic-cooled—II–10, Piqua (12.5 MWE); I–13 (50 MWE); I–18 (200 MWE). I cannot understand the programing of I–13 and I–18 since it is implied that these be started before full operating experience is obtained on II–10.

Sub-Class B''. Relatively good neutron economy—

Family 2. D_2O-moderated: These systems have high neutron economy and therefore intrinsically lower fuel costs than do the proton-moderated systems. They pay for this by higher capital costs. This is a type for which a sequence of increasing larger reactors probably makes good sense, since the capital costs per KWE are undoubtedly significantly lower for large systems.

Species a: D_2O-cooled. There are three embodiments, II–12, Carolina-Virginia (17 MWE 1962), I–1, D_2O power component reactor (O–60 MWE 1960), I–4 (100–250 MWE, 1963). This is an interesting type and the proposed sequence is reasonable; the timing seems confused, however, since as far as I know, I–1 will not be completed before II–12 is started.

Species b: Gas-cooled. There are three embodiments, II–3, East Central Group (50 MWE, 1963); I–16 (200 MWE, 1966) which use some inert gas, and I–8 (10 MWE, 1965) which uses steam). I tend to prefer this system over the D_2O-cooled, since the available temperatures are higher; the sequence, and its timing, seems reasonable.

Species c: Na-cooled. There are two embodiments—II–9, Chugach (10 MWE, 1963); and I–17 (200 MWE, 1966). As with all sodium systems, these tend to be expensive unless the size is large. There is therefore incentive to pursue this type beyond II–9.

Species d: Organic-cooled. Presumably the two embodiments I–13 (50 MWE, 1964) and I–18 (200 MWE, 1967) could be D_2O-moderated, though this is not specified. This system resembles the Na-cooled in that the coolant is at low pressure. It is inferior to Na with respect to radiation stability and temparature achievable; it is superior in that the required plumbing is cheaper. The use of organics as coolants is basically an attractive idea and could be very important. I prefer organics as coolants in systems using good moderators, to organics used as moderator and coolant.

Family 3. Graphite-moderated: These systems also have good neutron economy (though not as good as the D_2O system), and therefore hold promise of low fuel cycle costs; they are high-capital-cost systems, and therefore large sizes are indicated.

Species a: H_2O-cooled. One embodiment, I–10 (300 MWE, 1963) is proposed. I see little intrinsic merit to this system since the coolant is at high pressure and the temperature is limited; this view would be modified somewhat if boiling and superheat were achieved as in the Russian graphite-water reactors.

Species b: Organic-cooled. Two possible embodiments, I–13 (50 MWE, 1964) and I–18 (20 MWE, 1967) are apparently indicated. I like this one better than the graphite-H_2O-cooled provided the radiation stability is found to be acceptable.

Species c: Na-cooled. Two embodiments, II–8, Nebraska (75 MWE, 1962); and I–17 (200 MWE, 1966) are indicated The neutron economy must be improved considerably beyond what has been demonstrated in the SRE in order for the merit of this system to become fully evident.

Species d: Gas-cooled. Two embodiments, I-2 (40 MWE, 1962) and I–16 (200 MWE, 1966) are indicated. Since the decision to pursue gas cooling has already been made, I only remark that in this case the proper path of development probably should include some very high-temperature, high-conversion ratio system.

Family 4. Beryllium-moderated reactors: No embodiments of this system are proposed.

The foregoing reactor taxonomy is summarized below.

32855—58——4

REACTOR TAXONOMY

Phylum I. High-utilization reactors (breeders):
- Class A. Thorium systems:
  - Family 1. Aqueous homogeneous, thermal breeders:
    - Species a. Two-region
    - Species b. One-region
  - Family 2. Fast and intermediate breeders
  - Family 3. Heterogeneous thermal breeders
  - Family 4. High-temperature liquid breeders:
    - Species a. Fused salts
    - Species b. LMFR
- Class B. Uranium-plutonium systems:
  - Family 1. Solid fuel, fast breeders
  - Family 2. Liquid fuel, fast breeders

Phylum II. Low-utilization reactors (burners; use less than 2–3 percent of fertile material):
- Class A. Highly enriched fuel:
  - Family 1. Liquid fuel burners:
    - Species a. Fused salts
    - Species b. LMFR
    - Species c. Aqueous homogeneous
  - Family 2. Solid fuel burners
- Class B. Slightly enriched or unenriched fuel
- Subclass B′. Relatively poor neutron economy:
  - Family 1. Proton-moderated
  - Subfamily 1″. H_2O-moderated:
    - Species a. H_2O-cooled
    - Species b. Boiling-water-cooled
  - Subfamily 1″. Organic-moderated:
    - Species a. Organic-cooled
- Subclass B″. Relatively good neutron economy:
  - Family 2. D_2O-moderated:
    - Species a. D_2O-cooled
    - Species b. Gas-cooled
    - Species c. Na-cooled
    - Species d. Organic-cooled
  - Family 3. Graphite-moderated:
    - Species a. H_2O-cooled
    - Species b. Organic-cooled
    - Species c. Na-cooled
    - Species d. Gas-cooled
  - Family 4. Beryllium-moderated.

As I have already stated, the most difficult problem that faces the Commission is to try to decide from the many, many possibilities which ones it wishes to pursue fully and without reservation. I use the words "fully" and "without reservation" advisedly, since it is much better to give full support to a few efforts than half-hearted support to many efforts. With this in mind, I would propose that, as a fundamental principle, the Commission adopt as *firm* policy, the wholehearted pursuit, leading either to successful systems or to insurmountable obstacles of some system in *each* of the four *classes:* Thorium breeders (class IA); uranium breeders (class IB); highly enriched burners (class IIA); slightly enriched burners (class IIB). The first two classes aim at full utilization of raw material as well as economical power; the second two classes aim only at low mills per kilowatt-hour and depend for their very long-term future on mining low-grade ores successfully. The present United States program, as is the world's program, is centered very heavily on class IIB, slightly enriched or unenriched, low-utilization reactors. I would like first to see a redress of this balance, with more effort going into the other three classes, even if it means cutting back on some of the types now pursued in class IIB.

To cut back some in class IIB may not be as difficult as it seems; most of the problems in IIB center around the fuel element. Could not the program for pursuing IIB involve itself more with developing the fuel element than with building reactors? It is not at all clear that the building of successive genera-

tions of *reactors* is a valid development instrument for achieving economic power if the real problem is the fuel element cycle cost. Bettering the reactor, without bettering the fuel cycle cost, may not help very much if the capital cost is already fairly low, as is the case with the boiling water reactors.

There remains the excruciating, but necessary, problem of making a choice within each class, especially since each system has its devotees, and someone will be hurt when the choice is made. Nevertheless, a choice must be made. I will venture to offer my opinion, but I warn that this opinion is biased, as is any opinion in reactor technology.

RECOMMENDATIONS

Class IA. Thorium breeders.—I strongly urge full support for family 1, the aqueous homogeneous, on the basis that it alone seems to offer the possibility of very short doubling time. If the present difficulties prove insurmountable, this would represent a major disaster for nuclear energy.

Family 2. Fast and intermediate Th breeders: I see no reason for pursuing these.

Family 3. Heterogeneous Th thermal breeders: These will emerge naturally from developments in class IIB.

Family 4. Fused salt or LMFR breeders: These will emerge from developments in class IIA.

Class IB. Uranium breeders.—

Family 1. Solid fuel uranium breeders: I strongly urge pursuing this system fully, even though its difficulties are at least of the same order as those of the liquid breeders.

Family 2. Liquid fuel uranium breeders: Basic work should continue on liquid fast breeders.

Class IIA. Highly enriched burners.—

Family 1. Liquid-fuel burners: One of the two possible high-temperature liquid burners should be supported fully. My choice is the fused-salt system.

Family 2. Solid fuel, highly enriched burners: These should not be pursued.

Class IIB. Slightly enriched burners.—For all of these systems fuel-element development is crucially necessary, and it is implied that such development is necessary.

Family 1. Proton moderated: It seems to me that the current crop of PWR's and BWR's is sufficient, as far as AEC support is concerned—that the proposed 200 MWE BWR's and PWR's are already covered by Commonwealth Edison's 180 MWE BWR and Con-Edison's 163 MWE. AEC support should be toward fuel-element development. As for the organic moderated, I believe the organic as *coolant* makes better sense than organic as coolant and moderator.

Family 2. D_2O-moderated, heterogeneous systems: These should be pursued seriously. I see no great merit in trying out four different coolants on large scale, especially since the fuel element is rather similar in all of these, and its development is essential. Why not choose two—say, gas and organic—and pursue these? A coalition with Canada on this system, with the large reactor partly financed by the United States, seems like a sensible idea.

Family 3. Graphite moderated: Since we have already embarked seriously on the gas and Na versions, why not stick to them? Actually, I am not very clear about the Na version; unless the neutron economy can be greatly improved, I see little advantage in it. I would like to see a detailed comparison between Na and organic-cooled before choosing one or the other.

Family 4. Beryllium moderated does not appear. I suggest that studies of this system continue.

ANSWERS TO SPECIFIC QUESTIONS

I have already pointed out that I consider economical power by breeding to be a *major program objective*, not merely a technical objective.

2. I would add as an additional technical objective: Developing methods for extracting uranium from phosphoria rocks and shales at costs which will make low conversion ratio systems economical. Unless we can, in fact, get uranium from these rocks at reasonable cost, we shall not be able to fuel our class IIB reactors economically in the long run.

3, 4. These are covered in my general comments and in the taxonomy.

5. The estimate of $500 per kilowatt energy is probably sound. However, I cannot understand where the 10^6 kilowatts comes from. This number is rather arbitrary and already assumes some judgment as to which projects in table I are pursued, which are dropped. Thus, I neither agree nor disagree with the cost estimate; I simply do not understand the basis for arriving at it.

On the other hand, I think a very major forward step has been taken when we state as a matter of policy how much we are willing to spend, over, say, 7 years, to achieve practical nuclear power. It is much easier to establish a program in such a vastly ramified field as reactors if one has an idea of how big a program one can afford. The figure of $875 million for the expanded program, plus, say, $125 million per year regular program, which amounts to about $1,750 million, seems to me to be ample to bring, say, one system in classes IA, IB, and IIA into full development (I estimate the cost at $250 times 10^6 for each system) and still leave $1,000 times 10^6 for the 4 systems of class IIB, which I have recommended (2 D_2O-moderated systems, 2 graphite-moderated, and continued fuel-element development for the proton-moderated system).

6. I agree completely that AEC must exert *positive* direction and assume full responsibility for the program. In my opinion, the power-demonstration program is simply not an adequate instrument to achieve successful nuclear power.

7. It seems to me that $1,750 million, if confined to 1 system from each of classes IA, IB, and IIA, and to 4 systems from class IIB, should be sufficient to make of nuclear energy a bona fide economical proposition which requires little further Government subsidy. I, therefore, object to the waiver of capital charges for fuel and heavy water, since this tends to promote certain reactor types artificially with respect to other types.

One final suggestion concerns the matter of building up an inventory of heavy water. Since heavy-water reactors do seem to have an attractive long-term outlook, it is most important that the United States continue to operate is present D_2O plants and stockpile heavy water for the time when heavy water as moderator is needed on a big scale. If D_2O is not stockpiled now, it will be very difficult to catch up with the long-term requirements.

TABLE I.—*Power reactors for new undertakings*

Project	Approximate electrical rating (megawatts)	Status	Approximate time interval for project
I-1. Heavy water cooled and moderated power components reactor.	[1] 0	Under study by contract with AEC.	1956–60
I-2. Gas cooled, graphite moderated	40	do	1958–62
I-3. Boiling water with nuclear superheat	10– 50	Proposal made to AEC	1958–62
I-4. Heavy water cooled and moderated	100–250	Under study by contract with AEC.	1958–63
I-5. Aqueous homogeneous solution	75–150		1959–65
I-6. Process heat reactor	[2] 0		1959–62
I-7. Fused salt fueled	10		1959–64
I-8. Steam cooled, heavy water moderated	10		1959–65
I-9. Intermediate energy neutron breeder	10	Under study by Southwest Atomic Energy Associates.	1958–6[illegible]
I-10. Water cooled, graphite moderated Hanford type.	300	Under study by contract with AEC.	1958–63
I-11. Pressurized water, enriched uranium fuel	200		1959–64
I-12. Boiling water, enriched uranium fuel	200		1960–65
I-13. Organic cooled reactor	50		1960–64
I-14. Liquid metal fueled reactor experiment	[3] 0		1959–63
I-15. 2 small 2d-generation industrial plants	15-40		1961–65
I-16. High temperature gas cooled, graphite or heavy water moderated.	200		1961–66
I-17. High temperature sodium cooled, graphite or D_2O moderated.	200		1961–66
I-18. Organic cooled reactor	200		1962–67
I-19. Sodium cooled fast or intermediate breeder	200		1963–68
I-20. Liquid metal fueled reactor	50		1963–68

[1] 60 thermal megawatts. [2] 45 thermal megawatts. [3] 5 thermal megawatts.

TABLE II.—*Status of power reactors underway or proposed* [1]

Project	Approximate electrical rating (megawatts)	Status	Approximate completion date
II-1. Boiling water, enriched uranium fuel.	180.0	Under construction by Commonwealth Edison Co.	1959
II-2. Pressurized water, enriched uranium fuel.	[2] 163.0	Under construction by Consolidated Edison Company of New York, Inc.	1960
II-3. Pressurized water, enriched uranium fuel.	134.0	Under construction by Yankee Atomic Electric Co.	1960
II-4. Boiling water, enriched uranium fuel.	[3] 16.5	Elk River Electric Cooperative and ACF; contract awarded by AEC under power-demonstration program.	1961
II-5. Boiling water, enriched uranium fuel.	[4] 50.0	Northern States Power Co. & Associates; contract awarded by AEC under power-demonstration program.	1962
II-6. Sodium cooled, fast breeder.	100.0	Under construction by Power Reactor Development Co.	1960
II-7. Sodium cooled, fast breeder.	20.0	Under construction by Argonne National Laboratory.	1960
II-8. Sodium cooled, graphite moderated.	75.0	Under construction by AEC and Consumers Public Power District of Nebraska under power-demonstration program.	1962
II-9. Sodium cooled, D_2O moderated.	10.0	Chugach Electric Association and Nuclear Development Corporation of America; research and development contract awarded by AEC under power-demonstration program; letter of intent negotiated on construction.	1963
II-10. Organic cooled, organic moderated.	12.5	City of Piqua, Ohio, and Atomics International; (proposal accepted) by AEC under power-demonstration program.	1961
II-11. Homogeneous aqueous slurry.	70–150.0	Pennsylvania Power & Light Co., Baltimore Gas & Electric Co., and Westinghouse Electric Corp.; research and development (proposal accepted) by AEC under power-demonstration program.	1964
II-12. D_2O cooled, D_2O moderated, pressure tube.	17.0	Carolinas-Virginia Nuclear Power Association, Inc.; (proposal accepted) by AEC under power-demonstration program.	1962
II-13. High temperature, gas cooled, D_2O moderated, pressure tube.	50.0	East Central Nuclear Group and Florida West Coast Nuclear Group; (proposal accepted) by AEC under power-demonstration program.	1963
II-14. Boiling water, enriched uranium fuel.	60.0	Announced February 1958 by Pacific Gas & & Electric Co., and Bechtel.	1962

[1] Reactors in operation as of January 1958 omitted.
[2] Additional 112 electrical megawatts from oil-fired superheater.
[3] Additional 5.5 electrical megawatts from coal-fired superheater.
[4] Additional 16 electrical megawatts from oil-fired superheater

[Reprinted from Nucleonics magazine, August 1958]

A GUEST EDITORIAL: POWER BREEDING AS A NATIONAL OBJECTIVE

Ever since it became apparent that nuclear reactors could be used for the production of electricity arguments have raged on the relative importance of breeder reactors. Some have felt that the development of breeders should be a matter of considerable priority. Others have felt that breeders should be worried about in the future when uranium supplies begin to dwindle.

Despite these differences of opinion, considerable progress has already been made on breeding in the United States. In fact, production of the first plutonium in a breeder was announced by the United States in 1953.

Breeding will undoubtedly be a topic of importance in the forthcoming discussions of the future United States nuclear power program. The subject will also be discussed rather fully at Geneva next month.

And so, in this issue of Nucleonics which is devoted in large part to a report on the United States nuclear fuel program, the editiors are pleased to publish the guest editorial below. It is written by the distinguished reactor scientist, Alvin M. Weinberg, who has been one of the most eloquent spokesmen for breeder reactors.—The Editor.

It is imperative that we clarify our national objectives in power-reactor development. The technological choice of path among the many possible reactor systems depends too sensitively upon the goal we seek to tolerate fuzziness or vacillation in the delineation of our goals.

The primary goal of our civilian nuclear power development generally is assumed to be the demonstration of reactors that will produce power economically in the United States—say, at 8 mills per kilowatt-hour or less. A secondary aim is to develop systems that make economic sense in other countries—say, at 10–12 mills per kilowatt-hour. The essential point is that the sole figure of merit that guides the development is mills per kilowatt-hour.

I wish to argue that to make mills per kilowatt-hour the sole basis for determining our course is shortsighted and wrong; an equally valid basis for guiding the development is neutron economy. I propose, therefore, that the achievement of practical power breeders be considered as important a goal for our power-reactor enterprise as the achievements of low mills per kilowatt-hour per se.

First, I shall make two comments on our present motivation in reactor development—one is concerned with the validity of the goal of low mills per kilowatt-hour, the other with the means by which we seek to achieve low mills per kilowatt-hour.

As to the validity of the goal of low mills per kilowatt-hour, I remark first that the incentive to achieve economic nuclear power quickly in the United States is not great because we have abundant fossil fuels. Moreover, the computation of mills per kilowatt-hour depends far too much on arbitrary accounting decisions, or transitory economic conditions, to make this a completely reliable and exclusive basis for deciding on a path of reactor development. Reactor technology is ponderous and time consuming; it is very dangerous to choose one path and to exclude another simply because the mills per kilowatt-hour, computed at a certain time in history and therefore greatly affected by a particular system of accounting or by the current material supply, shows one system to be more economical than the other.

A good example of how such economic considerations can lead one astray is the history of gas cooling in the United States. The early studies of gas cooling, for example one made by the Commonwealth Edison group, were based on high inventory charges. The gas-cooled systems, because of their rather low material efficiency, therefore suffered by comparison with other systems because of such accounting. More recent studies, based on lower inventory charges, now suggest that gas-cooled systems could lead to favorable costs even in the United States.

I do not, of course, argue that we discard mills per kilowatt-hour as a figure of merit; I simply state that there are other figures of merit—thermal efficiency, capital cost, neutron economy—the achievement of good performance in any one of which can also determine a technological path. Any estimate of mills per kilowatt-hour implies a certain weighting for each of these characteristics of a reactor; because there is much arbitrariness in such weighting, I am not convinced that low mills per kilowatt-hour as computed on the basis of *current* economics is necessarily the whole story. In my view at least one of these other considerations—neutron economy—is as important as the overall computed mills per kilowatt-hour.

My other point is concerned with the means for achieving low mills per kilowatt-hour. If we leave breeders out of consideration, then all of the current reactor types by means of which we hope to achieve low mills per kilowatt-hour are really very low-conversion-ratio systems. Even with Pu recycle, they do not claim to burn more than about 3 percent of the total uranium.

If one is content with burning only a small fraction of the uranium, just so long as the mills per kilowatt-hour is low, then one must be willing to look at all the

schemes that seek to achieve only low mills per kilowatt-hour. In particular, one should include in the competition the high-thermal-efficiency, highly enriched liquid burners—the U-Bi and the molten salt systems. They, too, burn only a small fraction of all the uranium—perhaps one one-hundredth instead of one-fiftieth or one-thirtieth. They make up for a slightly lower conversion ratio by very high thermal efficiency and reduced chemical processing costs. That these systems operate with highly enriched fuel tends to obscure their relation to the systems that operate with slightly enriched fuel. In both cases most of the fertile uranium is thrown away—in the one case in the diffusion-plant tails, in the other case in the waste storage tanks—and therefore the two systems should be viewed as competitors. It is my own impression that in the competition for a reactor that will achieve 8 mills per kilowatt-hour, the very high-temperature, fused-salt, low-conversion-ratio burner could become a very significant contender.

My main concern, however, is to restate the case for making the achievement of successful power breeders once more a *primary* objective for United States reactor development, equal in status with the achievement of low mills per kilowatt-hour. The argument is simple and has been stated many times: If nuclear energy is to supply a *major* fraction of our energy, then there is just not enough low-priced uranium to enable us to base our economy on low-burnup systems (I include 20,000 Mwd/ton, i. e., ~3 percent, as "low" burnup).

Consider a nuclear-power industry in the United States equal in magnitude to our present electrical industry—say, 150×10^6 kw(e)—based on plutonium-recycle, 20,000-Mwd per ton reactors. Assuming a 0.8 load factor and 25 percent overall thermal efficiency, this would require 9,000 tons of uranium *per year*, in addition to about 75,000 tons' inventory. This is to be compared with the latest estimate of 150,000 tons of uranium recoverable in the United States at $10 per pound, perhaps 1 million tons available at $30 per pound.

Thus there is hardly any argument against the *ultimate* need for breeding. What then are the arguments against making the achievement of economical power breeders a *primary* objective of the United States nuclear power program? I think all of the arguments center around the belief that somehow these devices are too difficult, too cumbersome. To this I say that if we do not pursue power breeders with full vigor, then one decade, and then another, and still another will slip by without our having such systems. We *may* not achieve successful power breeders even if we work hard at them; we *certainly* shall not achieve successful power breeders if we do not work hard at them.

But at least as far as the aqueous-homogeneous thorium breeder is concerned, I am not prepared to concede that the breeders are necessarily more cumbersome than customary nonbreeders. The complications in the homogeneous reactors are in the plumbing and piping systems where all can see rather than, as in the heterogeneous reactors, in the chemical plant or in the metal-fabrication plant whose complications are tucked away out of sight but are nevertheless real.

There is certainly no argument against the view that an economical power breeder that utilizes 35–70 percent of the raw material is superior to an economical nonbreeder that utilizes only 3 percent of the raw material. Generally, we think it will take longer to achieve the former than the latter. But in the United States we could get along without *any* large-scale nuclear power for a couple of decades. We could use this time to develop the devices that make sense in the long run—the power breeders.

Yet, although we have years of grace, we cannot wait indefinitely. We cannot, for example, wait for controlled thermonuclear energy. The uncertainties in the Sherwood business are far greater than the uncertainties in the breeding business. It is grotesque to compare the feasibility of power breeding with the feasibility of controlled thermonuclear energy, just as it is grotesque to devote, on power breeders, no greater effort than is being spent on thermonuclear energy.

We are trying to develop a technology, not just for the next decade nor even for the next century. We are trying to develop a technology which, if truly successful, can assure mankind a source of energy for thousands of years. I think future generations will judge our efforts to be tragically shortsighted if, in our scramble for low mills per kilowatt-hour, we not only waste the world's supply of neutrons, but also fail to devote full effort to finding ways of using completely our nuclear fuel.

ALVIN M. WEINBERG,
Director, Oak Ridge National Laboratory.

E. I. DU PONT DE NEMOURS & COMPANY, INC.,
Wilmington, Del., October 31, 1958.

Mr. JAMES T. RAMEY,
Executive Director, Joint Congressional Committee on Atomic Energy,
Washington, D. C.

DEAR MR. RAMEY: As you requested in your letter of August 21, I am giving you here my comments on the Joint Committee's leaflet, Proposed Expanded Civilian Nuclear Program.

A crystallized statement of program objectives like that on page 4 is a useful administrative tool. It is necessarily too simple to convey the committee's whole attitude. It is to be hoped that it can be well enough agreed on in Congress to be an assurance to industry of a high probability of continued activity over, say, the next 10 years at a reasonably sustained level. If so, it will remove a major difficulty, if I understand the industrial attitude correctly. In my opinion 1970 may not see nuclear power at competitive cost in the United States, but a program of the sort outlined will surely tell us under what conditions competitive power can be achieved.

I think a 2-year differential for competitive power in high-cost free world nations may be too low if the achievement of competitive power in the United States depends on using the foreign experience to refine the United States design. Two years is hardly one reactor generation, and one such generation is probably the minimum time to overcome the differential in cost of conventional power between the high-cost nations and the United States. However, considering the uncertainty of estimate involved in setting up a time schedule of this sort, I would not suggest a change in either the 1970 or 1968 dates.

The general technical objectives seem to me to be adequately inclusive. I feel sure that time will prove that an attempt to say today which ones will have proved most important by 1970 would be rather futile. Nevertheless, a choice of distribution of effort must be made, somewhere within the four groups represented by your committee, the Commission's contractors, and other industry. I hope that this will be done in a way that will allow for diversity of views. This will require a permissive attitude toward a competent group that is warmly enthusiastic about a line of work even if the enthusiasm of the directing agency is only tepid.

Though there is mention of uranium oxide on page 6, paragraph 5, I think that (h) on page 5 might read "*use of natural uranium as a fuel.* This will particularly require metallurgical and ceramic development to permit operation at high temperature and high burnup of pure or nearly pure uranium in the form of metal or refractory compounds."

My feeling about the technological program is that it says too little about basic research. Development basic to a field but not necessarily directed toward a specific reactor is well covered on pages 6 and 7. However, there are some forms of basic research (in contrast to development) that you might have mentioned as a class. This class is research that is carried on in a field in which there is a known problem, but which does not attack the problem directly because there is no clear way to do so or because the clear routes of attack have failed to give the desired result.

For example, we badly need ways of making uranium and zirconium more resistant to high temperature water—more like stainless steel. Perhaps if we knew more about the thin, impermeable films that form on stainless steel, aluminum, and zirconium and that give them various degrees of resistance to hot water, we could find a way of reaching our objective. A study of such films, involving their structure, chemistry, and adhesive properties, would be quite a basic research project in contrast to development. As a second example, we need cooling liquids of low cross section, high boiling point, and high stability to radiation (or a rapid recombining rate under radiolytic conditions). A basic study of inorganic liquids other than metals might uncover unsuspected liquids, just as a study of complex systems has uncovered many unsuspected highly magnetic materials.

I admit the improbability of both my specific examples, and wish I could give better samples of the class I am trying to describe. We need new inventions like fissium or the rejuvenation of old fuel by extraction of metal melts with molten fluxes. Such inventions are most likely to arise from a situation in which basic research of the sort I have mentioned is being carried on vigorously.

The proposed list of reactors in table I appears to me to represent adequately a range of study from which the economics of nuclear power should emerge. Experience may of course change the list.

The average cost of $500 per kilowatt mentioned on page 8 seems low to me. A figure in the $700–800 area appears more likely. Would it not be possible to estimate the total annual cost to the Government more explicitly?

I have no comments on questions 6 and 7.

Again and again through the document I have noted an attempt to write flexibility into the program. I think this is highly desirable, even if it weakens the assurance of stability which the document is intended to provide.

It is important that as soon as is practical after a reactor experiment operates and looks promising a good-sized prototype, of say 100,000–200,000 electrical kilowatts should be built and its design and performance scrutinized closely by experienced operating, design, and technical men. Probably the biggest percentage cost reduction in the history of any reactor type will come when the next reactor after the prototype is built and operated. The assessment of the prototype and its performance should really be the crucial point in reactor history: if it is unfavorable that type should be shelved until technology or economics have changed to make it attractive.

Very truly yours,

ATOMIC ENERGY DIVISION
HOOD WORTHINGTON, *Director, Technical Division.*

NUCLEAR DEVELOPMENT CORPORATION OF AMERICA,
White Plains, N. Y., November 3, 1958.

MR. JAMES RAMEY,
Executive Director,
Joint Committee on Atomic Energy,
Congress of the United States,
Washington, D. C.

DEAR MR. RAMEY: In reply to your letter of August 21, let me say at once that I am very pleased to see your serious attention to the framing and statement of objectives for the civilian power program, and to the formulation of policy for its guidance. Also, the longer intervening period has allowed more time for reflection on the roots of the program.

In regard to your particular questions, I would comment as follows:

(1) These objectives involve, to some extent, matters of national policy on which I can speak, if at all, only as an individual citizen. I have no way of judging, for example, whether the position of leadership of the United States in the eyes of the world in peaceful applications of atomic energy is better fortified by the development of central station reactors or by the development of, say, space propulsion reactors.

One would assuredly not question the importance of power reactors. Even if they cannot produce a golden age, as Wigner has remarked,[1] they may make it possible to maintain our iron age. The question as to whether they should be particularly emphasized among the other peaceful applications (such as research, transportation, space exploration, education, high temperature processing, etc.) is less easy. Again, I have no way of judging, for example, whether the free world and the United States' position in it is more strengthened by providing one large power reactor or a hundred small university reactors.

On balance, it is my impression that power reactors do rightly deserve the major interest at present, but that some of the other applications should have serious (even if smaller) program attention also.

The times proposed seem reasonable if the goal in (*a*) is to be competitive in the higher cost areas of the United States by 1970. In connection with (*b*), it might be considered that atomic energy may come to be somewhat accepted even before it has become strictly competitive costwise, if it brings increased freedom from dependence upon distant and foreign fuel supply sources, e. g., the Near East.

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[1] Acta Physica Austriaca, Band XI, 1958, Heft 4, p. 410.

(4) Here, again, it appears that matters of national policy become involved. Thus, with the same disclaimer as before, let me reply to your question, for reasons which are partly in a different dimension of discussion, in the following manner:

The list of reactors in table I is not ideal, in my opinion. I would, instead, urge consideration of the proposition that the only central station reactors to receive attention henceforth should be natural uranium types and Pubreeder reactors.

I suggest that this path would best serve the interests of the United States and our allies, and would permit reduction in the complexity and cost of the program.

(2) While some details and points of emphasis would vary if the fundamental reactor types were redefined, the objectives set forth are well chosen. "Cheaper systems" to make more economical combination uses of lower cost components, techniques and processes might perhaps be given individual mention in the list, but is, in any case, present implicitly.

(3), (5) The duel program of general reactor research and development on the one hand, and a respectable number of selected new reactor projects on the other, at about equal average dollar level, should be able to provide a good balance between learning what to do and doing it, and between nearer and longer range systems. The size of the total program might be reduced somewhat if the basic reactor scopes were simplified. The estimates, as made, appear reasonable.

(6) These policies appear to me to be in the right direction, and to have a good prospect of accomplishing the purpose. I hope that in their execution it will be possible to pursue the best technical suggestions and ideas, whatever be their source, and to make best use of the industrial contractor system for the most spirited furtherance of the program and for the healthiest growth of the industry itself.

(7) It is possible that the domestic program may require further attention in the irradiated fuel area (reprocessing facilities, storage and disposal facilities, plutonium credit, etc.), in addition to types of financial assistance such as those discussed at the bottom of page 12.

I could not suggest, at this time, what further needs may appear in the foreign program.

Sincerely yours,

GALE YOUNG, *Vice President.*

GENERAL NUCLEAR ENGINEERING CORP.,
Dunedin, Fla., October 22, 1958.

Mr. JAMES T. RAMEY,
Executive Director, Joint Committee on Atomic Energy,
Washington, D. C.

DEAR MR. RAMEY: This is in reply to your letter of August 21, 1958, in which you asked for comments on the "proposed expanded civilian nuclear reactor program."

Since I had full opportunity to comment during the meetings while the document was being prepared, and since I am mentioned in the document as having acted as consultant, I believe a letter giving my views would be inappropriate.

Perhaps my comments would be most helpful if made after I have had a chance to see what reaction your letter has obtained. In particular, the specific reactors to be slated for development and the organization for doing it are points which are of major interest. Since the Atomic Energy Commission must act for the Government in all these matters, it seems to me that the program cannot develop substance until and unless the AEC joins in it.

Yours truly,

W. H. ZINN, *President.*

APPENDIX 3

REPLIES FROM PRIVATE POWER COMPANIES AND ORGANIZATIONS

(NOTE.—Page numbers and reference to tables, etc., in the following letters refer to the Joint Committee publication of August 1958, entitled, "Proposed Expanded Civilian Nuclear Power Program.")

AMERICAN ELECTRIC POWER CO., INC.,
New York, N. Y., November 3, 1958.

Mr. JAMES T. RAMEY,
Executive Director, Joint Committee on Atomic Energy,
Congress of the United States, Washington, D. C.

DEAR MR. RAMEY: This is in response to your letter of August 21, acknowledged on August 29 and later discussed with you by telephone early last month. You had requested comments by November 1 on the committee memorandum of August 1958 entitled "Proposed Expanded Civilian Nuclear Power Program." I regret that several prior commitments abroad have kept me from submitting comments until now and hope that they will not arrive too late to be of use to you and the committee.

I have had some difficulty in arranging my comments in the order and under precisely the topics of your questions. I think, however, that you will find my comments do touch on the essential points suggested by your questions.

I should like to make it clear that, while I am associated with two industry groups engaged in nuclear power projects and a member of several industry committees dealing with matters atomic, in what I have to say in the following pages I am speaking solely on my own behalf and as president of American Electric Power Co.

1. *The desirability of a stated national program.*—At the outset, I would like to say that the attempt to develop a statement now of a proposed expanded civilian nuclear power program impresses me as a sound idea. And the circulation which you have given to your staff paper among the many people interested in atomic energy should elicit ideas and comments which should be very helpful to the committee. I appreciate the considerable effort that entered into preparation of the memorandum and I think it represents a substantial contribution to the problem. I am troubled by many features of the memorandum; I have tried, however, to make my criticisms as constructive as possible.

2. *The word for flexibility in such a program.*—Before dealing with more specific matters, I want also to express a general point of view which I believe is somewhat different from that reflected in the memorandum. As I have indicated, a stated national reactor program seems to me a good thing to have. But in a field as fluid as this one, and one which in turn is so closely tied together with another highly fluid field—the entire problem of national and world energy resources—I believe strongly that any national program should have the utmost flexibility built into it to allow for changing conditions. The memorandum does refer to this concept in a number of places. As will appear, however, I think such a program can—with advantage—be carried out with even more flexibility than the one set forth in the memorandum.

3. *The need for machinery for continuous evaluation.*—I believe also that much more thought needs to be devoted to establishing effective machinery for continuous evaluation and reevaluation of the results of research and development work and of the overall energy problem so that successive steps in the national reactor program will always reflect up-to-date knowledge. On this matter, too, I shall amplify my views at a later point.

4. *Program objectives.*—The three stated program objectives, namely (a) achieving and demonstrating competitive nuclear power in the United States, (b) achieving and demonstrating it somewhat earlier in high energy and friendly nations, and (c) fortification of the position of leadership of the United States in the peaceful application of atomic energy are each important goals. But they are not all inclusive. For example, I would give equal emphasis to the de-

sirability of bringing the development of atomic power as soon as possible and as nearly as possible within the framework of exploitation of conventional energy resources. By this, I have in mind that a healthy, ultimate utilization of atomic energy can best take place with manufacturers of equipment and other interested industries working together with electric power systems—public and private—and their engineers, free from the special restrictions and special forms of assistance which are necessary during the transition period that we are now going through. I attach great significance to this objective because I do not think we shall ever achieve a sound basis for commercial exploitation of atomic energy, either in the case of public or private power systems or other industries, until this goal is achieved.

5. *Target dates.*—In addition to believing that the program objectives should be thus amplified, I have serious reservations about setting a target date for competitive nuclear power of 1970 for the United States and 1968 for the high energy cost free-world nations. Establishing target dates for competitive nuclear power, whether within the United States or abroad, is meaningless unless the location is specified. In this country, given the present prospect for conventional fuels, atomic power is going to be competitive in different parts of the country at different times. I make this observation because the outlook for cost of conventional fuel varies and will continue to vary rather widely from one section of the country to another. While I think the aim of achieving competitive atomic power in free-world countries abroad earlier than in the United States is desirable, here again geographic variations ought to be taken into account and a sweeping target date is very debatable.

The criterion for competitive atomic power is so different from area to area that what may be achieved in one area by 1968 or 1970 may not be achievable in still others until 1980 and in still others may not be achievable even within 25 years. Therefore, if target dates were to be meaningful, it would be necessary to specify what area or areas we are speaking of and to have a variation in time scales.

Moreover, the setting of such target dates would require, in my opinion, much more careful evaluation of energy situations in the United States and in other countries than has yet been made. For example, the Paley report, which is perhaps the best study ever made of our energy requirements over the next 25 years, is probably not adequate as a basis for setting a specific date, whether 1970, 1975, or any other date within that range.

We have also had dramatic evidence during the past decade of the changing outlook with respect to conventional fuel supplies here and abroad—in important instances much more favorable today than many people thought possible in the times immediately after World War II.

It is also relevant in this connection that we have learned here and abroad that, no matter what the effort, achievement of competitive nuclear power is a much more difficult goal than many first thought.

6. *Assistance to our friends abroad.*—While I firmly believe we need a vigorous and ambitious civilian nuclear power program, with overall objectives as I have stated them, I must also express a reservation to the idea, which seems to me to be reflected in the memorandum, that we should give our friends abroad all possible assistance to achieve nuclear power in significant quantities as soon as possible. I do not quarrel with the program for Euratom under which we are going to help the community countries develop six large nuclear plants within the next 5 years. That is certainly a "significant" quantity. But even in the case of these countries the question needs to be asked whether "information and not power per se" (memorandum, p. 1) is the important question. The memorandum seems to me not to be wholly consistent on this point. The point itself is really a corollary to the points I have made with respect to target dates.

7. *Desirability of a flexible, continuing 10-year program.*—Having expressed these reservations about program objectives, target dates, and foreign aid, I nevertheless think that it is a good thing to try to project a civilian nuclear power program over a period of perhaps 10 years. But I believe such a program needs to be formulated in provisional terms having definiteness for only 2 or 3 years forward with machinery for continuous study and examination to enable the Congress and Commission each year to lay a solid basis for projection forward for another year. In this way, until we have finally mastered the problem of competitive atomic power, we would have a continuing 10-year program with a great deal of built-in flexibility but always with 2 or 3 years of that program definite. My own view is that a program so evolved would be much more likely to achieve the goal of maximum speed in the economical development of competitive atomic power here and abroad.

8. *General technical objectives and listing of miscellaneous reactor concepts.*—Many of the general technical objectives outlined in the memorandum have come to be accepted as desirable routes of progress. The same is true of a number of the reactor concepts listed in table I. I am nevertheless troubled about the appearance of rigidity that detailed listing of technical problems and reactor concepts takes on when formulated under the auspices of such an important body as the Joint Committee—even allowing for the qualifications written into the memorandum.

In the case of the technical objectives, they cannot be listed in detail in a meaningful way unless much more attention is given to the problem of their relative importance and the timing for achieving individual technical goals.

An example of what I have in mind is the statement in paragraph (f) on page 5 that "Every effort to utilize the radiation and fission products in economic and beneficial ways should be made." Our experience with conventional technology does not suggest that this objective be given the highest priority. For many years we have been concerned with utilization of such waste products as CO_2 and ash from coal-burning power stations. Progress has been made in dealing with both of these waste products but, on the whole, it has not been significant. Yet this has not prevented us from developing a conventional technology in the United States that has given us fuel-based electric energy supply which is among the lowest costs in the world.

Another example of matters that, in my view, need to be dealt with differently occurs in paragraph (*b*) on page 5, which speaks, among other things, of the desirability of "standardization of joints and fittings." It seems to me that one of the things we can be certain of is that almost any standardization, at the present stage of development, will retard rather than promote technical progress.

Taken as a whole, I am also troubled by a detailed listing of technical objectives which may mistakenly be regarded as exhaustive. Any description of such goals needs to be done in such a way that it will encourage constructive thinking along new lines which no one may have in mind at the moment.

As for table I and its list of specific reactors, I am skeptical about the ability of any group to describe desirable future reactors with the definiteness implied in table I and the memorandum. Again I am mindful of the observations made in the memorandum that, in the end, perhaps only half of the list would be carried out and that "Program flexibility is essential in order to permit adjustments based on technological advances" (pp. 1, 8, 15). My difficulty, as I explained earlier, is one of emphasis and with the present lack of machinery to assure adequate, continuous evaluations both of reactor technology and advances in it and the related conventional energy problem.

The flexibile type continuing 10-year program, already described, plus evaluation machinery, to be discussed shortly, would avoid these dangers.

9. *Role of AEC and industry in national civilian reactor program.*—As background for my comments, I suggest that experience to date shows that we should be proceeding vigorously (1) with further research and development on proven concepts which have shown clear indications that they can be significantly improved by such research and development, and (2) with vigorous research and development on new concepts that appear to have a reasonable chance of success. Other concepts which may be intriguing but not promising enough to warrant intensive development might then be carried forward on a limited basis. I realize that ideas of the kind I am here suggesting may be implicit in the memorandum. I think they need to be made more explicit.

During the transition period between the present and competitive nuclear power, the Atomic Energy Commission will, of course, have an important part to play in virtually all aspects of reactor development. But if I am correct in believing that one of the primary goals is to achieve commercial exploitation of atomic energy as nearly as possible conforming to the present framework for conventional energy, that role should be a constantly diminishing one. And that role, as fashioned in the first instance, should be such as best to promote future diminution in AEC's part.

To this end I believe that more flexibility in AEC aid to industrial companies and utility systems—public and private—and their engineers is required during the transition. There will still be important research and development for the AEC to carry on itself, including perhaps the construction of certain small prototype reactors. But most prototypes and all large-scale reactors, whether first or later generation, need not and should not be part of AEC's job.

Under my view, too, there would be no room for further projects in which the AEC owned the reactor portion of the project. This method complicates arrangement to such a degree that I am skeptical about the clarity of results, economic and otherwise. Since it is knowledge we are after, clarity in results is essential.

Instead of AEC reactors, I recommend the following measures, in addition to those now available and some proposed in the memorandum, as calculated to achieve a quicker, better, and more economical program.

(*a*) AEC financial support for promising research and development work without requiring those undertaking the work to commit themselves to building a costly reactor. The requirement, not of existing law but existing policy, of coupling aid for worthwhile research and development programs to a commitment to build a plant seems to me wholly unsound and uneconomic, when the very investigations involved or others in progress may show that the plant should not be built. The requirement has the effect, I think, of discouraging work outside the AEC that ought to be encouraged. Various devices can be employed to assure that AEC financial assistance will be used effectively. One excellent device is that AEC aid be conditioned on a 50–50 contribution by the agency to whom the aid is given. Because the outside agency would in this way be bearing a substantial part of the cost, it would have the same motivation to assure effective use of the total research and development money to be spent on any specific project. Adoption of this suggestion, I am informed, would require no change in present law. It would require a change in policy.

(*b*) Where prototypes or uneconomic first or later generation large-scale experimental reactors are found desirable, agencies outside the AEC should be encouraged to undertake all of them. Where necessary for this purpose, an outright grant should be made to the outside agencies to cover the major portion of the difference between costs justified by economic considerations and the total costs. I recognize that the details of this proposal—which has also been made by others—would have to be carefully worked out to avoid excessive grants and to assure equitable treatment of public and private power systems and industrial concerns. In addition, in view of the way section 169 of the Atomic Energy Act of 1954 has been construed in practice, this proposal would require a change in interpretation or an amendment to the law. But I think the problems in working out and administering such a plan are no more difficult than other problems which have thus far been dealt with successfully by the Congress and the AEC. And the rewards in developing a successful program along these lines should be great enough to induce everyone to approach it in the same spirit, say, as the very difficult indemnity problem upon which so much progress has been made, legislatively and in Government and in industry.

As I indicated at the outset, a decisive consideration underlying this proposal is the conviction that we shall not master the new technology and achieve genuinely competitive atomic power until our conventional institutions, public and private, have taken over the work and devoted to it all their wealth of engineering and economic experience and all they can in the form of financial participation.

10. *Evaluation machinery.*—In the general approach which I advocate, the Congress and the AEC (as well as other appropriate Government agencies) would always have a decisive part in major policy decisions during the transition period. Nevertheless I think our experience demonstrates that we have not yet fashioned adequate machinery for the technical evaluations and reevaluations that must be made in a continuing program. I have had occasion in a number of places and before the Joint Committee in 1956 to make recommendations on this point. In a letter I submitted to the then chairman, Senator Anderson, to complement testimony I gave in that year, I made the following suggestions:

* * * * * * *

"But the question of the general adequacy of our reactor program in scale, scope, and timing cannot be disposed of soundly just by discussion among laymen. In the end, of course, Members of the Congress, AEC Commissioners, industrial managers and others, who are essentially laymen, should decide these issues. But, in order for their decisions to be made wisely, they must be made upon the basis of the best informed and most expert technical evaluation possible of the progress that is being and can be made.

"3. This brings me back to the suggestion I made in colloquies with you, Senator Gore and Senator Jackson, in the course of my testimony: that is, the sugges-

tion for setting up of a high-level technical evaluation group to provide the Commission and the Congress with a comprehensive technical basis for their difficult decisions. My thought is that the group should report to the Commission periodically on its investigations and findings with regard to reactors and reactor development. I have in mind that such a group could be assigned the task of investigating and reporting on such matters as the status of the current program; the results achieved to date; the difficulties and failures encountered; the positive experiences with better behavior or performance than originally anticipated; the significance of all these in terms of the current program and on the further projection of the program; to the extent possible, analysis of the results in the principal foreign centers of reactor technology development; and, finally, recommendations for action involving further expansion of the existing program, acceleration or retardation of certain parts of it, and initiation of new projects.

"In my view, the overriding emphasis in selecting members for such an evaluation group should be technical competence. The group would need a substantial number of members from the power industry; and the topflight engineers that I would seek can be found both among the public and private power systems. But I think we have got to avoid treating this as a public versus private power question. The evaluation group would have to be composed of men with a background of sufficient general experience to treat the relevant questions in the technical terms that will provide the illumination the Commission and the Congress need in forming their own judgments. Also, as indicated in my testimony, the technical evaluation group would have to have topnotch scientists among its members. And since our manufacturers have done and are doing such important work in the field, we need to look also to them to supply some of the important technicians who would constitute the evaluation group. If such a group, composed of widely gaged technicians, made periodic reports to the Commission, based upon solid investigation and analyses, the Commission could, in my opinion, have a much better basis for programing reactor development than it now has and the Commission, the Joint Committee, and the country would have a much more substantial assurance that the interests of the country in this vital area of action were being properly advanced."

* * * * * * *

It seems to me that it is still not too late to consider this matter afresh. I would hope that the possible effectiveness of new, continuing evaluating machinery has not been changed because of the Ad Hoc Advisory Committee on Reactor Policies and Programs recently announced by the AEC. Since my view is that we need much more than an ad hoc committee, I see no conflict between current institutions and the new and more ambitious evaluation group which seems to me to be needed.

In sitting up a continuing body for evaluations, thought must be given to complementing its work by establishing means to obtain adequate, continuing evaluations of the situation with respect to conventional energy resources here and abroad.

11. It is, of course, not enough to say that we need adequate, continuing evaluation machinery. Nor is it enough simply to give, as I have done, my general conception of that machinery. There needs to be thoughtful, disinterested work on details preliminary to the setting up of such a new body. For this purpose, the long-established British practice is relevant. I have always believed that it was unfortunate that we had not assimiliated British experience in government administration where it has been standard practice to utilize parliamentary committees of inquiry. The nature of the process in the United Kingdom has, in the great majority of cases, brought about public acceptance of findings because of their intrinsic disinterestedness and the thoroughness of the inquiry. The Joint Committee experience with the McPinney Committee is also an encouraging precedent. I would use a similar device but address it to the narrower problem of advice on the detailed matters involved in creating a new institution to give us the evaluation machinery that we have thus far lacked.

12. Finally, I find it difficult to comment at all on the matter of estimated costs which is dealt with in the memorandum. It may well be that the memorandum strikes the right figures but I think it will be plain from the tenor of this letter that, in my opinion, we need to do much more preliminary work before we can speak with confidence of a level of expenditure which is to be continued over a period of the next decade.

Sincerely yours,

PHILIP SPORN.

AMERICAN & FOREIGN POWER CO., INC.,
New York, N. Y., November 17, 1958.

Mr. JAMES T. RAMEY,
Executive Director of Staff, Joint Committee on Atomic Energy,
Congress of the United States, Washington, D. C.

DEAR MR. RAMEY: Forwarded herewith are the comments of the American & Foreign Power Co., Inc., regarding the questions raised in your letter of August 21, 1958.

1. Do you agree with the three major objectives of the program? If not what changes would you recommend?

We are in general agreement with the three objectives stated although the dates mentioned in the first two objectives seem to be somewhat arbitrary. The short time interval between the demonstration of competitive nuclear power abroad and in the United States seems optimistic.

2. Are the general technical objectives adequate? If not what additions or deletions would you recommend?

It is not clear how the technical objectives listed are related to the three stated major program objectives. Certainly plant costs and fuel costs must be reduced if the goal of competitive power is to be achieved but it is not possible to itemize in advance the specific improvements which must be combined to achieve lowest cost. The program should be reexamined from time to time and modified if necessary to assure proper orientation in the framework of the overall objectives. We believe that the objective of early demonstration of competitive nuclear power will be reached most expeditiously by concentrating on the few most promising types of reactor.

3. Please comment on the adequacy of the scope of the technological program.

We agree that the technological program should include fundamental research, development, construction, and operation of nuclear powerplants. We believe that every effort should be made to have the utility industry participate in any project for the construction and operation of a full-scale or prototype nuclear powerplant.

4. In your opinion, is the proposed list of reactors in table I the best list for this program? If not, what changes would you recommend?

The list of reactors seems to be very comprehensive. We note in the report that construction of about half of these projects is expected to prove unjustifiable on technical or economic grounds. We hope that careful analysis will be made in each case before commitments are made for construction to assure that the project will make a significant contribution toward the goal of economic nuclear power. We hope that selection of projects for support will not be made primarily on the basis of novelty. We do not believe that the number or variety of reactor plants built or the total number of nuclear kilowatts are in themselves important in judging the value of the United States program.

5. Do you consider the cost estimates to be reasonable? If not, please point out the areas in which you disagree.

We believe the estimated costs are generous for the contemplated program.

6. What is your opinion of the policies on organization and administration proposed on page 9? Will they adequately implement the positive leadership required for success of the program?

We agree that AEC should have responsibility for conducting a base program of research and development. We agree also that AEC should carry through reactor experiments if necessary to determine the technical feasibility of reactor concepts. However, we do not believe that AEC should undertake the construction of large-scale demonstration plants. The initiative for installing full-scale or prototype plants should come from industry in order to gain as much as possible from the application of commercial incentives. It is apparent that industry cannot bear fully the excess cost of building and operating nuclear plants on the urgent schedule fostered by the Government over the cost of the same capacity in conventional plants. Hence the Government should be prepared to provide financial assistance of a kind which will encourage industry to build those nuclear plants which contribute toward the goal of economic nuclear power. We believe that the types of assistance proposed on page 10 fail to provide the incentives necessary for industry to make the effective contribution which it is able and willing to make.

We believe that AEC should be given flexibility to consider unsolicited proposals on their merits. At the same time it may be desirable occasionally to

select projects for support on a competitive basis. In such cases we believe it is in the Government's best interest to allow sufficient time for preparation of sound proposals by the proposer and adequate evaluation by AEC. One approach might be to set periodic cutoff dates, say 6 months apart, for submission of proposals, with the proposer given freedom to specify such details as type of reactor, power level, and amount and kind of assistance requested.

7. If it should later prove necessary, what other types and amounts of assistance would you recommend for the domestic program? For the foreign program?

We believe that the need exists now to provide the means whereby the utility industry can participate effectively in the program. As discussed above we believe that financial assistance covering a share of the excess construction and operating costs is essential if the pace of nuclear plan construction is to be accelerated. If necessary, the restrictions of section 169 of the Atomic Energy Act of 1954 regarding use of AEC funds in the construction and operation of developmental powerplants should be modified so as to permit the granting of financial assistance covering a share of the excess costs. Such assistance should preferably be provided without requiring that AEC take title to the reactor or other essential part of the powerplant. On the other hand, if the necessary assistance can only be granted to a construction and operating project through arrangements under which the AEC must own the energy producing facility, the provisions of the act should be revised to remove the gross discrimination against investor-owned utility companies which virtually excludes such companies from participating in such projects by the "preference clause" embodied in section 44 in conjunction with other provisions of the act.

We are more directly concerned with the foreign atomic power program. The types of assistance listed on pages 11 and 12 appear to be reasonable. Of these a satisfactory solution to third-party liability problem is especially important for investor-owned utilities abroad.

Sincerely yours,

H. W. BALGOOYEN.

COMMONWEALTH EDISON CO.,
Chicago, Ill., October 9, 1958.

Hon. CLINTON P. ANDERSON,
Vice Chairman, Joint Committee on Atomic Energy,
Congress of the United States, Washington, D. C.

DEAR CLINTON: Jim Ramey has asked my comments on the staff's proposed expanded civilian nuclear power program.

At the outset I should say that the staff proposal, in my opinion, is a remarkably good document despite the fact that in certain respects I am in disagreement with it.

The suggestions which I shall make were made in substance to Mr. Ramey during the course of the meetings. For various reasons these suggestions were not accepted.

Nevertheless, I feel that you would like to have from me comments based on my frank views on what will do the most to advance the nuclear-power program in a sound way.

My comments are these:

1. Along the lines of your June 18 speech before the Nuclear Energy Writers Association, I believe that at the bottom of page 10 a paragraph (e) should be added to the list of types of assistance by the Commission. The list would then read as follows:

(a) Waiver of established Commission charges for use of source and special nuclear materials.

(b) Loan of heavy water without charge.

(c) Performance in AEC laboratories without charge, or at less than full cost, of mutually agreed upon research and development.

(d) Research and development contracts under section 31 (a) of the Atomic Energy Act of 1954 in support of specifically described research and development work in connection with design, construction, and operation of nuclear powerplants.

(e) *A contribution in the form of a grant of not to exceed 90 percent of the estimated difference between the cost of a nuclear plant and a conventional plant of the same electrical capacity. Any such type of assistance would involve consideration of revision of section 169 of the Atomic Energy Act of 1954.*

If this suggestion is adopted, it will, of course, necessitate the elimination of the last paragraph on page 12.

2. I believe that the joint ownership of nuclear power projects (reactor ownership by the AEC and power facilities by utilities) is a costly, complicated, and inefficient way to advance the nuclear power program.

Therefore, I suggest that the material under "B" on page 11 be revised as indicated below. I shall copy the entire section and draw lines through the portion which I believe should be eliminated.

1. The second part of the framework for cooperating with industry would take the form of announcements of invitations for proposals to participate under AEC sponsorship, direction, and ownership (of the reactor portion of the project) in the development, design, construction, and operation of—

(a) Experimental prototype reactors.

(b) Other specific reactor projects which are deemed to be especially timely and desirable by the AEC but for which no reasonable proposal has been received.

2. Such projects would be constructed at (a) AEC sites with the electric power, if any, to be consumed in connection with site operations. ~~(b) At sites of municipal, State, Federal, or co-op owned systems, with arrangement similar to the second-round power demonstration program,~~ (c) ~~or at sites where power may be distributed to private companies consistent with section 44 of the Atomic Energy Act.~~

~~3. The projects constructed under subsections 1 and 2 of this section would be operated under contract with the Commission for a period of time deemed by the Commission to be advisable, for research and development purposes, but not to exceed 10 years.~~

~~Upon the expiration of such period, the AEC with respect to figure 2 (b) and (c) shall offer the reactor and its appurtenances for sale to the cooperating utility. With respect to 2 (a) and in the event no utility elects to purchase under 2 (b) and (3), AEC shall dismantle the reactor and appurtenances.~~

I have asked Titus LeClair to comment directly to Jim Ramey on certain other matters of lesser importance.

Sincerely,

WILLIS GALE, *Chairman.*

COMMONWEALTH EDISON CO.,
Chicago, Ill., October 10, 1958.

Mr. JAMES T. RAMEY,
Executive Director, Joint Committee on Atomic Energy,
Congress of the United States, Washington, D. C.

DEAR MR. RAMEY: Thanks for the copy of the printed statement on the proposed expanded civilian nuclear power program. It certainly looks good in print.

A most important part of this report is the program objective on page 4. We discussed that in the meetings of the advisers, but the more I look at it the more difficult it becomes for me to defend the exactness of the dates when competitive power cost is not an exact term. To be more specific, the Pacific Gas & Electric Co. estimates that their Humboldt Bay nuclear plant, to be completed in 1962, will produce power at a cost competitive with fossil-fuel power at this particular location where oil is costly, and the plant can operate at high load factor because of its location remote from the larger generating stations. On the other hand, very few of us believe that nuclear power can compete with fossil fuels in the heart of the Texas oil and gas fields until long after 1970.

I suggest that the program objectives on page 4 be reworded as follows:

~~(c)~~ (*a*) Fortify the position of leadership of the United States in the eyes of the world in the peaceful applications of atomic energy, particularly with regard to power.

~~(b) Achieve and demonstrate in high-cost free-world nations nuclear power competitive in cost per kilowatt hour by 1968.~~

(*b*) *Achieve and demonstrate nuclear power competitive with the cost of conventional fuels in free-world nations and in high-cost fuel areas in the United States in the early future.*

~~(a) Achieve and demonstrate in the United States power competitive in cost per kilowatt hour by 1970.~~

(*c*) *Achieve and demonstrate nuclear power competitive with the cost of conventional fuels in a substantial part of the United States by 1970.*

You may recall that I previously thought the list of reactors in your table I. contained some types which may not prove desirable. The latest EEI report gives you an encouraging amount of parallel for the near term. Congratulations.

Would you be willing to omit the figures for rating on the projects for later years? This would reduce the degree of firmness and not prejudice future changes.

Mr. Gale is writing directly to Senator Anderson concerning some of the suggestions I made to you as we went along. If you should decide to adopt these suggestions, it might be necessary for you to change the subject headings on pages 10 and 11.

It certainly has been a pleasure to work with you. Hope you came back from Geneva with renewed enthusiasm.

Sincerely yours,

T. G. LeClair,
Manager of Research and Development.

Consolidated Edison Company of New York, Inc.,
New York, N. Y., October 28, 1958.

Mr. James T. Ramey,
Executive Director, Joint Committee on Atomic Energy,
Congress of the United States, Washington, D. C.

Dear Mr. Ramey: Thank you for sending me a copy of the committee staff study on a proposed expanded civilian nuclear power program and for inviting my comments.

Naturally I am gratified to note the use made of the material contained in the report of the Technical Appraisal Task Force on Nucuear Power of which I have the privilege of serving as Chairman. I can add little of real substance to the suggestions contained in that report.

Since individual points of view so largely influence individual judgments on the details of any broad program, I shall confine myself to an independent expression of my personal reactions. For the sake of brevity I shall include them within the framework of the seven questions in your letter of August 21.

1. While it is implicit in the study, I suggest that an explicit statement of a fourth objective on page 4 would be helpful. The last sentence on page 2, "The ultimate goal of the entire program is to develop strictly commercial plants which would be economically competitive without financial assistance from the Government," expresses the thought I have in mind. Perhaps a restatement of objective (*a*) on page 4 would accomplish this.

I realize that target dates have their uses but they also have disadvantages. A certain degree of initial discouragement and also possible ultimate disillusionment might be avoided by qualifying the years 1968 and 1970 as hopes rather than firm expectations.

2. In technical objectives (*a*) and (*b*) particularly, and to a lesser extent in some of the others, there is implicit the idea of what I shall call cheaper safety. Necessarily at this stage of development we must be, and we are, ultra conservative in matters of containment, shielding, fuel handling, etc. This conservatism is expensive. Might it not be desirable to recognize this explicity and perhaps to add another technical objective dealing more specifically with this problem.

3. I can add noth'ng to the discussion in the task force report.

4. In table I on page 16 I note the addition of a number of items to the list in the task force report. In the main these appear to be "second generation" or "full scale" reactors. Certainly they are worth keeping in mind. I do have mental reservations that the dates associated with them may be rather optimistic. I realize that the text emphasizes the need for flexibility in the program but a table of this sort too easily gets dissociated from the text. Since there is ample room on page 16, I suggest it would be desirable to use footnotes rather liberally so that as much of the story as possible is presented as part of the table.

5. Design and development costs associated with pioneering projects are so difficult to estimate that I hesitate to express an opinion as to them. However, I feel the cost estimates for a second generation or full scale reactor should be sufficiently accurate to assure that the total cost of electrical energy from such a plant with its first core would be approximately competitive, say not more than 25 percent greater than that from a conventional plant, to warrant proceeding with the project.

6. I suggest making the above proviso regarding overall costs in connection with the last sentence of paragraph (*b*) on page 9. With respect to paragraph (*c*) I believe that more consideration might well be given to the time limits to be specified in the invitations. Surely a period of time corresponding to that involved in the study by the Commission leading to the issuance of an invitation would not seem unreasonable.

7. I believe experience will suggest what, if any, other types and amounts of assistance will be necessary. Certainly it would be wise to provide for special arrangements as suggested in section C on page 11.

I hope these comments will be helpful. I shall, of course, be glad to be of any further assistance at any time.

Sincerely yours,

J. F. FAIRMAN, *Senior Vice President.*

THE DETROIT EDISON CO.,
Detroit, Mich., November 15, 1958.

MR. JAMES T. RAMEY,
Executive Director, Joint Committee on Atomic Energy,
Congress of the United States, Washington, D. C.

DEAR MR. RAMEY: We wish to thank you and the members of the Joint Committee on Atomic Energy for the opportunity to submit our comments concerning the proposed expanded civilian nuclear power program. As you know, our company since 1949 has been among those who have firmly promoted the early development of atomic power. We have either spent, or committed more than $42 million of the company's funds for the objectives of Atomic Power Development Associates, Inc., Power Reactor Development Co., and Detroit Edison parts of the Enrico Fermi fast neutron breeder reactor project. Also that in order to carry out improvements in this reactor and the continuation of research toward the accomplishment of a second generation of the fast reactor would require still additional funds.

We agree that an expanded civilian nuclear power program is highly desirable. Though we would feel that such a program should be largely spontaneous on the part of industry, it is apparent that incentive and sponsorship must be created, and that orderly development must be maintained. These, it seems to us, are proper functions of the Atomic Energy Commission. I shall comment further concerning such programs later in this letter.

We agree basically with the program objectives as stated on page 4. However, realizing the difficulty to predict accurately the time to complete research and development work, and the time required for the design and construction of pioneering reactor projects, we think that the dates given should be considered somewhat flexible in nature. We can agree that the large expenditures of funds which appear to have been made to keep PWR on schedule are justifiable but we can see no real reason for similar actions in the presently proposed plan. Such funds can be used much more effectively for broad program purposes.

We suggest that the final part of objective (c) be revised to read "* * * peaceful applications of atomic energy for electric power and other useful purposes." In our minds the ancillary applications may well enter importantly into the economics of atomic power and should be continuously a consideration in power development programs.

We also suggest a fourth objective substantively "Establish criteria for the selection of sites for atomic powerplants and other atomic facilities." The committee, we are confident, recognizes the present somewhat confused situation concerning plant site selection.

We believe that the statement "General Technical Objectives" should be broadened by the addition of one item concerning safety standards and strengthened by the rearrangement of the subheadings as follows:

(*a*) Safety Standards for Construction and Operation
(*b*) Higher Temperature Steam
(*c*) Lower Cost Components
(*d*) Lower Cost Field Assembly
(*e*) Better Fuel Elements
(*f*) Use of Plutonium as Fuel
(*g*) Use of Natural Uranium as a Fuel
(*h*) Improved Breeding Ratios
(*i*) Less Costly Reprocessing
(*j*) Lower Cost Waste Processing and Disposal
(*k*) Realization of Incidental Benefits

The order in which the above items are listed is not of critical significance but we believe the above arrangement provides a better grouping of closely related matters. We would be pleased to submit suggested specific language for the new item (*a*) should the committee wish to include the subject in the final program draft.

A technical program of the scope and kind in question necessarily is complex. While the present statement seems sufficiently comprehensive, we should remember that with the rapid advances now being achieved, what may appear to be adequate probably may be far from proper or adequate next year. There is a marked similarity between the list of "Power Reactors for New Undertakings," listed in table I, and the reactors recommended for study in the Edison Electric Institute Task Group Interim Report. Though we agree that all of the proposed reactors are worthy of study, we feel that all construction programs should await the careful evaluation of such studies. It accomplishes little to spend money for the construction of reactors—even small prototypes—unless it can be clearly demonstrated that the type in question offers definite promise of contributing significantly to the achievement of the stated objectives.

We are concerned, too, with the effects which Euratom, British, or other European programs may have upon the overall picture. Certainly, with the exchange of information provided in the Euratom agreements and to some extent in the agreements with Britain, it should not be necessary to duplicate in the United States the work which is to be done by others. We have the feeling that our overseas friends will make important contributions.

With these thoughts in mind, we believe that the Atomic Energy Commission should be given the maximum amount of flexibility in deciding what reactors are to be built as the program advances in an orderly way. We think it would be inadvisable for Congress to approve a limited program at this time in such a manner that the freedom of the Commission to meet conditions as they develop would be severely handicapped.

In closing I would like to make one suggestion concerning the fast or intermediate neutron breeder reactor which is listed in table I. As the design and construction of the three fast breeder reactors progresses (EBR–2, Dounreay, and PRDC), substantial sources of valuable information are being developed which would suggest that the design of a second generation reactor of this type might well be undertaken by the end of 1961. At that time sufficient operating experience should be available from these three projects which could well justify the initial work on such a reactor. On that basis, construction might be undertaken in 1963 or 1964 and the reactor ready for operation in 1965 or 1966 or perhaps even earlier.

I do wish to thank the Joint Committee for inviting us to comment upon this proposed expanded program. We hope that, with the discussion that will likely follow, the present state of atomic power development can be rationalized and clarified for the guidance of everyone concerned.

Sincerely,

WALKER L. CISLER.

DUKE POWER CO.,
Charlotte, N. C., November 6, 1958.

Mr. JAMES T. RAMEY,
Executive Director, Joint Committee on Atomic Energy,
Congress of the United States, Washington, D. C.

DEAR MR. RAMEY: Thank you very much for your letter of October 30 in reference to the Joint Committee report, Proposed Expanded Civilian Nuclear Power Program. I must apologize for putting you to the trouble of following up your original letter of August 21 in reference to this matter.

You have received no reply from this company as our president, Norman A. Cocke, is a member of the Edison Electric Institute committee on atomic power and this committee has either already submitted or is in process of submitting a reply on behalf of the committee. As Mr. Cocke is a member of this committee it seemed unnecessary for us to respond individually for this company.

Your courtesy in seeking comments by this company is appreciated, and we hope that the reply being made by the Edison Electric Institute committee will satisfy your requirement.

Sincerely yours,

O. J. MILLER,
Executive Vice President.

EDISON ELECTRIC INSTITUTE,
New York, N. Y., October 31, 1958.

Mr. JAMES T. RAMEY,
Executive Director, Joint Committee on Atomic Energy,
Congress of the United States, Washington, D. C.

DEAR MR. RAMEY: This letter is submitted on behalf of the Edison Electric Institute committee on atomic power in response to your letter of August 21 inviting comments on the proposed expanded civilian nuclear power program. Our committee appreciates the opportunity you have afforded it to comment on this program. A brief description of the Edison Electric Institute and the makeup of its committee on atomic power are attached.

In responding we will address ourselves primarily to considerations of the broader policy questions that arise in this field and accordingly will not attempt to provide answers to questions 2 through 5 which relate principally to technical matters. In this regard, however, we direct your attention to the recent report of the institute's technical appraisal task force on nuclear power entitled "Status and Prospects of Nuclear Power—An Interim Survey." This report contains much information that bears directly on many of the technical matters raised in your questions, including suggested areas of research and development to be pursued, reactor concepts warranting investigation, proposed time tables for various projects, and other technical considerations. The Joint Committee on Atomic Energy and the Atomic Energy Commission were furnished copies of this report in March of this year. In September, a revised edition, including newly added appendixes, was published and copies were similarly distributed.

The following is responsive to other points in your letter concerning the draft program:

Question 1: Do you agree with the three major objectives (p. 4) of the program? If not, what changes would you recommend?

In general, we believe that in order to bring into proper focus the place of the Government in the development of peaceful applications of atomic energy, a rearrangement of the sequence and some clarification of the objectives might be helpful. Objective (*c*), page 4, we believe is the primary objective of the program, namely, to "Fortify the position of leadership of the United States in the eyes of the world in the peaceful applications of atomic energy, particularly with regard to power."

Objectives (*a*) and (*b*) are in reality secondary ones which are of significance in relation to the primary objective. These are stated as (*a*) to "Achieve and demonstrate in the United States nuclear power competitive in cost per kilowatt-hour by 1970," and (*b*) to "Achieve and demonstrate in high-cost free-world nations nuclear power competitive in cost per kilowatt-hour by 1968." The significance of this differentiation is very real inasmuch as the secondary objectives (*a*) and (*b*) would be of little significance to the Congress if objective (*c*) were not of primary importance. Accordingly, we would suggest that objective (*c*) be stated first.

The importance of attaining the three objectives set forth in the report is brought into focus by the statements at the bottom of page 4 and top of page 5. "The combined program for attaining these first two objectives will accomplish the third objective of fortifying our world leadership in peaceful applications of atomic energy. This leadership is important in fostering an increasingly close relationship with our foreign friends and allies on a much broader base than purely military cooperation." It is this third objective which is the primary interest of our national policy.

In accomplishing these objectives, however, the nation must be ever mindful of the importance of its historical business system and economy. As the acknowledged leader of the free world and champion of the free-enterprise system, the United States must not, in attempting to fortify one aspect of its leadership, adopt means that are contrary to this system. Furthering Government ownership and controls serves to weaken the very system the Nation is dedicated to strengthen.

Accordingly, we recommend the addition of a fourth objective. It should clearly state that this program, in keeping with section 1 of the 1954 act, should be so conceived and administered as to maximize participation in and ownership of facilities by private enterprise and thereby assure that normal business incentives and the Nation's normal business system will at the earliest practicable date replace Government control, direction, and ownership.

Such an objective would be in keeping with section 1 of the Atomic Energy Act of 1954 which states in part that "the development, use, and control of atomic

energy shall be directed so as to * * * strengthen free competition in private enterprise." We believe that the objectives of any national program of nuclear power development in the United States should take firm cognizance of this principle.

Additional to this major consideration is the one of how best to attain the stated objectives and the ultimate goal of the entire program as set forth at the end of the summary, "* * * * to develop strictly commercial plants which would be economically competitive without financial assistance from Government."

We believe both the program objectives and ultimate goal can best be attained through a program designed to make maximum utilization of the strengths of our normal business system rather than one based on Government ownership or on the detailed controls of a planned economy. In this regard, it should be recognized also that commercial costs, which are the sole basis for determining economic competitiveness, can only be validly known through industry ownership and operation of nuclear plants.

With reference to objectives (*a*) and (*b*), we raise a question relative to assigning specific years by which competitive nuclear power must be attained. We believe it to be more appropriate to establish the objective of carrying forward a vigorous and orderly program of nuclear power research, development, and construction, consistent with technological developments, aimed at maintaining United States leadership in the eyes of the world in the peaceful applications of atomic energy by achieving competitive nuclear power in the United States and abroad at the earliest practicable dates, presently undetermined. The words "earliest practicable dates" imply the expenditure of what can be agreed upon as reasonable amounts of money, resources, and manpower consistent with conditions prevailing from time to time and consistent with technical progress. It might well be that this course would result in attaining the objectives before the dates specified.

With reference to the dates set forth in objectives (*a*) and (*b*), the question might also be raised whether a 2-year time span between the achievement of competitive nuclear power abroad and in the United States is not too short in view of the generally large fuel cost differential. If dates are to be specified, a 5-year span might be more realistic and capable of being attained, if any but the very highest United States fuel cost areas are to be included.

We believe also that for the purpose of clarifying the program, it will be necessary to define more specifically what is meant by the phrase "nuclear power competitive in cost." Some nuclear plants now under construction in the United States might, under conceivable conditions, be able to generate power more cheaply than fossil-fuel-fired plants at certain isolated high fuel-cost areas in the United States. A case in point is Alaska. On the other hand, if the phrase were to mean competitive in cost with power from plants in the lowest cost fuel areas of the United States, the situation is obviously quite different. It is probable that the intent of this phrase lies somewhere between the two extremes shown, but in any event, greater clarity will be helpful. Calculations of power cost involve consideration of many factors, including capital charges, load factor, and fuel costs that are not inherently a measure of the efficiency of the generating unit. The meaning of this phrase in the objectives, therefore, should be more specifically defined as to these factors too.

Also, it should be made clear whether a nuclear plant is to generate economic power initially in order to be competitive, or whether it will be so considered if it is expected to attain that goal during its lifetime. Similarly, with reference to objective (*b*), more definite conditions probably should be established to describe what is meant by "high cost free-world nations," giving due weight to the ability of such nations to utilize nuclear power in the amounts produced from high-capacity units.

We, of course, concur with objective (*c*) of fortifying the United States position of leadership in the peaceful applications of atomic energy, particularly with regard to power. We believe it to be the primary objective of our Nations' efforts. We concur also that in the research and development period ahead, this leadership should be measured in terms of technology and not in terms of quantity of nuclear kilowatts. This principle is recognized in the statement on page 8" * * * the object of the program is information, not power per se."

Question 6: What is your opinion of the policies on organization and administration proposed on page 9? Will they adequately implement the positive leadership required for success of the program?

With reference to basic policies in organization, we believe that it is of utmost importance that flexibility, both in administration and technical decisionmaking, be provided for. It is well recognized that such flexibility is much easier achieved in an administrative agency than in the Congress. Accordingly, we believe it to be important that the details of handling the technical and administrative phases of any program should be delegated to the AEC to be carried out within the broad framework of policy established by the Congress.

We believe the Atomic Energy Commission should carry important responsibility for research and development in power reactors only during the transition to commercial nuclear power. It should be clearly expressed in paragraph (*a*), page 9, that the intent is not for the AEC to have this continuing responsibility over the indefinite future but rather that such responsibility should be transferred to industry as rapidly as feasible.

With reference to paragraph (*b*), page 9, we believe that AEC's primary role in reactor development should be in the areas of investigating promising reactor concepts, conducting research and development, and constructing and operating experimental reactors, such as EBWR, SRE, EBR 1 and 2 and HRE 2. Beyond that point, AEC's role should be to provide necessary assistance to industry in the latter's construction and operation activities together with the necessary additional research and development associated with such activities. We believe that only through such cooperation with industry in the construction of both experimental prototype and large-scale plants will the program be maintained on a basis that will insure economic feasibility at the earliest practicable date.

Detailed Government control of the program can result in basic technical decisions being made by a limited Government group on a noncompetitive basis. We believe that better results are certain to be obtained if decisionmaking is decentralized and there is opportunity provided for industrial initiative and competition. Paragraph (*c*), page 9, and paragraph 1, page 10, appear to set the stage for detailed and virtually exclusive Government control by requiring specific AEC designation of projects to be supported. The program should not only allow, but should effectively encourage projects proposed by industry. Section C, page 11, "Special arrangements," provides for this in exceptional cases, but we feel that such projects may well provide the most productive results and should be the normal pattern rather than the exception.

The philosophy contained in paragraphs (*c*), page 9, and 1, page 10, is directly contrary to the spirit of the Atomic Energy Act of 1954 which was designed to give industry greater, not less, participation in the development of atomic power, so that the cost-cutting incentives of the United States business system could be put to work to maximum advantage in this field. If the AEC is to be charged with the responsibility of designating the type, size, and design of projects to be supported under the power demonstration program—other than in exceptional cases—then industry will for the most part be deprived of the vitally needed initiative to develop promising reactor types.

With respect to proposals under the extension of the power reactor demonstration program, it is important that ample time be allowed for the submission, approval, and negotiation of such proposals from industry. Experience has shown that these matters cannot reasonably be expected to be accomplished in a period of a few months as has been stipulated in the 1958 Authorization Act. The language of paragraph (c), page 9, should permit the thorough investigation and discussion, with discretion allowed to AEC, as to the time to be given for a response to an invitation.

Paragraph 2, page 10, states that projects designated by the AEC for an extension of the power reactor demonstration program should be based on reasonably well-de reloped technology and should not require extensive research and development work. Also, on page 1 of the report, the inference is made that the power reactor demonstration program will be limited to "second generation plants." If this is the intent, industry will be precluded from participating in most of the reactor projects listed in table 1, as the majority of these are first generation reactors. We believe it should be made clear that first as well as second generation reactors should continue to be included in the power reactor demonstration program. Otherwise, it will not be possible for industry to bear the substantial portion of the estimated cost of the proposed program which is anticipated at the top of page 9, and it will be necessary for the program to be funded primarily with taxpayer dollars.

We concur in the thought expressed in the first sentence of paragraph 4, page 10, "The Commission would consider requests for research and development

assistance under somewhat more flexible terms than previously." We feel further that Government assistance should not be limited to specific items but, rather, should encompass whatever reasonable form of assistance a proposing company or group of companies finds it necessary to request. If this principle is followed, the Government will be able to award a project to that group making the most favorable proposal from the standpoint of least cost to Government.

It is suggested that a paragraph 6 be added after paragraph 5 at the top of page 11 to establish, for those projects designated by AEC, a procedure for obtaining industry participation. Under this procedure, AEC might specify in broad terms the type, size, and other characteristics of a desirable project. Industry would be invited to make proposals to undertake such a project, such proposals to include the amount of financial assistance requested from the Government, together with the form (research, development, construction costs, etc) such assistance would take. The group submitting the most favorable proposal to the Government would be awarded the project.

With regard to section B, page 11, "Government-owned plants," the principle should be recognized that it is basically undesirable to have federally owned reactors on any utility system, public or private. AEC ownership should not be extended beyond the stage of reactor experiments at Commission sites or small reactor plants at Commission installations. These reactors should be operated only so long as they are deemed to be valuable from a research and development standpoint. Projects involving larger reactors should be submitted to industry for proposals in accordance with the new paragraph 6 suggested above and should be constructed, owned, and operated by industry. This principle is basic if operation of nuclear reactors is to emerge as other than a Government-owned industry.

Question 7: If it should later prove necessary, what other types and amounts of assistance would you recommend for the domestic program? For the foreign program?

Our response to this question will be limited to considerations of the domestic program, since the great majority of the electric utility industry has no direct relationship with the financing or construction of powerplants in foreign countries.

The answer to this question depends upon the urgency for a speedup of the whole program. Industry has indicated a keen interest in the development of economic nuclear power. Many manufacturing companies are investing sizable sums of money in nuclear research and development. Electric utility companies are presently participating in a substantial number of nuclear power development projects involving expenditures by those companies of over $500 million. Annual expenditures for these projects by electric utility companies are now running on the order of $100 million per year.

If a further speedup of the program is considered necessary, additional participation in nuclear power development by industry will be essential to achieve the national objectives set forth; hence, it is likely that the types and amounts of assistance indicated under "Privately owned plants," on pages 10 and 11, will not be adequate to bring about the desired additional efforts. For industry to make its maximum contribution to these additional efforts and at the same time enable the program to be carried out at lowest cost to Government, it will be necessary to increase the amounts and types of financial assistance.

Such assistance, whether to manufacturers or utilities, must be flexible enough to encourage research and development of all promising reactor types, and should include but not be limited to, the forms of assistance noted in page 10. Assistance should be provided in such amounts and types as to assure that projects can and will be undertaken by industry on a competitive basis. The provisions setting the form of Government financial assistance we believe should be broad and not be limited by preset formulas. Reference is made in this regard to our answer to question 6, above.

At the bottom of page 12, it is pointed out that expanded Government financial assistance will involve revisions of sections 44 and 169 of the Atomic Energy Act of 1954. We support revision of section 169 to provide for increased financial assistance under the proposed program. We have on numerous occasions before the Joint Committee on Atomic Energy advocated deletion of section 44 from the 1954 Atomic Energy Act. It might well be pointed out here that section 44 makes paragraph 2 (c), page 10, of the proposed program practically meaningless as there are very few locations in the United States where power could be distributed to private companies consistent with section 44.

GENERAL COMMENTS ON TECHNICAL ASPECTS OF PROGRAM

Paragraph 2, on page 15, appendix, reads as follows: "It should be recognized that specific projections of desirable projects within the program become less firm as time is extended. Program flexibility is essential in order to permit adjustments based on technological advances. The program must be subject to constant review to make certain new concepts are evaluated rapidly and projects proved not feasible are weeded out."

We concur in this statement and feel the thoughts expressed cannot be overemphasized. There is always the danger in setting up a long-range program of this nature of being too specific and, hence, too rigid. While we do not raise a question regarding any of the proposals shown in table No. 1, we call to your attention the fact that the mere listing of such proposals in a proposed expansion program by the Joint Comittee lends such weight and authority to them that it becomes difficult at a future time to deviate from the list, or modify the list as later research may indicate. Developments in the years immediately ahead may markedly alter the technical picture, and the program should provide the necessary built-in flexibility to take full advantage of such developments. We do not believe that the intent of the proposed program is to limit the AEC in its approach to this problem, but we do reiterate that the mere existence of a reactor list for priority tends itself to so limit selection of types.

In summary, as this new field of energy unfolds in the United States, it seems to us to be particularly important that at each stage of the development of the new field, prime consideration be given to the maintenance of our normal business system. Whatever we have in the way of productive capacity in this country can be credited to that system, and as we enter this new field of energy, every effort should be made to protect and strengthen it. Hence, whatever program of nuclear power development is proposed should be carried out within the framework of our Nation's traditional system. Such a program should be designed to create an environment in which the inventive and productive capacity of industry can most effectively be utilized to achieve the national and international objectives at the earliest practicable date. Detailed Government controls and Government ownership of nuclear powerplants will not serve to create this environment and will be detrimental to the achievement of the program objectives. Maximum participation by industry on the other hand will achieve optimum progress at least cost to the taxpayer. The need for flexibility, both technical and administrative, in carrying out such a program is of the utmost importance.

We appreciate this opportunity to discuss the August 1958 draft of the proposed expanded civilian nuclear power program and hope our comments will be of help to you.

Very truly yours,

ELMER L. LINDSETH,
Chairman, Edison Electric Institute, Committee on Atomic Power.

The Edison Electric Institute is a voluntary association of electric light and power companies in the United States. Its member companies serve 75 percent of the Nation's electric users and over 96 percent of all customers served by the investor-owned segment of the utility industry.

NAMES AND BUSINESS AFFILIATIONS OF THE EEI COMMITTEE ON ATOMIC POWER

Elmer L. Lindseth (chairman), president, the Cleveland Electric Illuminating Co.
Walker L. Cisler, president, the Detroit Edison Co.
W. J. Clapp, president, Florida Power Corp.
Norman A. Cocke, president, Duke Power Co.
Charles B. Delafield, vice president, Consolidated Edison Company of New York, Inc.
Edgar H. Dixon, president, Middle South Utilities, Inc.
Philip A. Fleger, chairman of the board, Duquesne Light Co.
George M. Gadsby, chairman of the board, Utah Power & Light Co.
A. S. King, president, Northern States Power Co.
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I. L. Moore, president, New England Electric System.
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R. G. Rincliffe, president, Philadelphia Electric Co.
Philip Sporn, president, American Electric Power Service Corp.
J. B. Thomas, president, Texas Electric Service Co.

GENERAL PUBLIC UTILITIES CORP.,
New York, N. Y., October 28, 1958.

Mr. JAMES T. RAMEY,
Executive Director, Joint Committee on Atomic Energy,
Congress of the United States, Washington, D. C.

DEAR MR. RAMEY: This is in reply to your letter of August 21, 1958, asking for comments by November 1, 1958, on the Proposed Expanded Civilian Nuclear Power Program, issued by the Joint Committee, as a committee staff memorandum, in August 1958.

General Public Utilities Corp., as a holding company, owns both an integrated domestic electric-power system and a foreign electric-power system serving Manila and environs in the Philippines. We therefore have an interest in both the domestic and foreign phases of your proposed program.

Mr. Louis H. Roddis, Jr., president of Pennsylvania Electric Co., a subsidiary of General Public Utilities Corp., has furnished us with a copy of his reply, and we generally concur in his comments and shall not burden you with repetition thereof. In addition, we thought that the following might be helpful to you.

The development of our thinking on a nuclear-power development program has been described to you in a series of communications to the Joint Committee and the AEC over the past 2 or 3 years. These begin with a March 2, 1956, letter to Senator Anderson, then chairman of the Joint Committee, commenting on the report of the Panel on the Impact of the Peaceful Uses of Atomic Energy against the background of our then initiated study of the feasibility of installing a full-scale nuclear powerplant on the system of Manila Electric Co., our Philippine subsidiary. On September 12, 1957, I wrote Chairman Durham summarizing our evaluation of the two proposals received for a Manila nuclear powerplant and sending a GPU report on nuclear-power program, dated August 26, 1957, summarizing our reasons for rejecting both proposals received. This GPU report outlined our proposed Saxton, Pa., hook-on reactor project, which was further explained in our letter of February 25, 1958, to Chairman Durham in connection with the last section 202 hearings. In addition, in a letter to Chairman Strauss, of AEC, on December 9, 1957, I made some specific suggestions as to a revitalized domestic program as well as some aspects of a feasible foreign program. Many of the comments in these communications have a direct bearing on, or relevance to, some aspects of your present proposed expanded program and are reiterated by reference as applicable to some facets of your proposed expanded program. For your convenience, copies of the letters referred to are enclosed.

Against this background, a few brief general comments are offered below in lieu of a question-by-question response to your letter.

1. Once the broad goals and overall financial dimensions of a long-range expanded civilian nuclear-power programs are determined by Congress, on recommendation of its Joint Committee, the responsibility for determining the detailed characteristics of the program and for its administration and technical direction should be conferred on a single agency on terms which give it the utmost flexibility in reaching the broad goals set.

It also appears to us that the statement of program objectives (p. 4) has these deficiencies:

(1) The use of the word "demonstrate" in stating the "program objectives" without delineating clearly what is meant;

(2) The failure in stating program objectives to recognize that conventional power cost levels vary considerably in different areas of the United States as well as among the free-world nations; and

(3) An apparent oversimplification of the concept of "power cost" and the components thereof and, also, of the highly variable processes, ground rules, and methods of estimating power-cost components.

2. The respective roles of the AEC, as a Federal agency, the utility industy (a term used here as including Government and cooperative power agencies and investor-owned utility companies), equipment manufacturers, and architect-engineers and/or construction engineers, in research and development work, in building, financing, and operating demonstration or other types of nuclear reactors, and in responsibility for cost estimates and construction schedules (pp. 9–11), are in need of clarification or explanation of seeming inconsistencies. For example, flexibility in the administration of such a technological development program in the assignment of various roles to these participating agencies and companies can be one of the most important tools for effectiveness. The more rigid the pattern of developmental efforts among the several participants, the slower and less certain is likely to be progress toward the ultimate goals.

Although this is recognized explicitly on page 7, this is less evident in other parts of the program.

3. On the basis of our study experience to date, we believe that, in seeking the most rapid progress toward economically competitive nuclear power, accumulation of actual construction and operating experience and the resulting attention to reduction of nuclear-fuel costs are more significant at this time than the possible reduction of capital-investment costs. This may require two or more core lives in any given reactor design before firm and reliable data from actual operating experience may be had. Hence, we would be inclined to question (1) the size of the proposed reactors in table I, which appear to be scaled up in an effort to realize by economies of scale some reduction in fixed-charge components of per-kilowatt-hour costs; (2) the fixing of specific dates for achieving the goal of competitively economic nuclear power applicable to specific power-cost areas. In our opinion, the statement of the technological program seems to put overemphasis upon building full-scale plants as compared with smaller scale prototype plants until the margin above competitive cost levels has been so narrowed that reaching for the economies of going full scale has reasonable prospect of closing the gap. Indeed, full-scale plants may tend to inhibit, in some respects, progress toward economic nuclear power, since the costs of such plants and the need for continuous use thereof to meet power load necessarily mean that such plants cannot be pushed to the safe limits of performance. This is one aspect of our Saxton, Pa., hook-on reactor project approach.

As a supplementary comment on the above and on the whole nuclear-plant-capacity question, it may be that the smaller unit reactor approach, by scaling down the individual reactor dollar commitments, could well lead to a larger number of units, each one improving on its predecessor, with wider industry participation. Each such unit would also provide an operating facility to be employed by a separate group (composed of participants from equipment manufacturers, architect-engineers, and the utility industry) striving for progress toward economic nuclear power by the process of step-by-step development which, in our opinion, offers the most promising path to progress. This step-by-step development is what made possible the improvement in conventional steam-turbine technology over many years to its present levels of efficiency, economy, and size. This is the approach that seems most fruitful to us, but we recognize that there are approaches along other lines that it may be desirable to encourage under different circumstances.

4. The technological levels already reached with water-type reactors in the nuclear steam-generator portion of the powerplant, in terms of pressures and temperatures, suggest that bridging the gap with existing steam-turbine technology by placing emphasis on developing nuclear superheat, as suggested by Mr. Roddis, may afford the most rapid progress toward economic nuclear power with this reactor type.

I appreciate the opportunity given to offer these few comments on the proposed program.

Very truly yours,

E. W. MOREHOUSE, *Vice President.*

GENERAL PUBLIC UTILITIES CORP.,
New York, N. Y., December 9, 1957.

Hon. LEWIS L. STRAUSS,
Chairman, Atomic Energy Commission, Washington, D. C.

DEAR CHAIRMAN STRAUSS: At the conclusion of the December 3 conference with electric utility representatives on an appraisal, reevaluation, and reshaping of a power reactor development program, Mr. Davis, for the Commission, invited further letter comments on the ideas expressed and questions posed by AEC at the conference. This letter is in response to that invitation after reflection upon impressions of the results of the conference.

1. I believe the conference had too many participants to give the Commission and staff in clear focus sufficiently definite answers to the questions posed to be really useful to the Commission in formulating a reshaped reactor-development program, either domestic or foreign. I think the Commission would be more likely to achieve this result if it now invited in a smaller group of not more than 12 to 15 representatives of electric utilities, both investor owned and Government owned, equipment manufacturers, and nuclear consultants or specialists, charged solely with proposing to the Commission for its consider-

ation a specific program, domestic and foreign, focused solely on feasible and reasonably rapid or accelerated development of nuclear-power technology in the next decade or two. This group should be asked to try to avoid giving weight to any nontechnological or noneconomic considerations of national or international politics or national security, these being matters for determination and evaluation by the Commission, joint committee, and Congress in their respective spheres of action.

A pattern for this kind of small-scale, technologically-oriented, advisory evaluation group will be found in one of the recommandations in 1951 of the ad hoc Advisory Committee on Cooperation between the electric-power industry and the AEC, dated March 1951.

2. There seemed to be general agreement that enthusiasm for starting new commercial-scale nuclear powerplants had flagged somewhat, largely because existing projects were finding capital costs and fuel costs higher and going higher than anticipated. This clearly points to the conclusion that a reshaped program revolves around finding ways of reducing both categories of costs if new utility ventures in nuclear research and development activities are to be induced and the period of time before nuclear power becomes competitive with conventional-fuel power is to be materially shortened, instead of stretched out.

Discussion of a revitalized domestic program along these lines indicated a need for (1) concentration of efforts to lower fuel-cycle costs—not only in fuel-element design, fabrication, and handling or shipment, but also in fuel reprocessing and waste disposal, and (2) in meeting the above need and recognizing that step-by-step methods of technological progress have been the history of the amazing development of conventional-fuel technology and equipment, acceleration of the application of existing reactor improvements or new designs, and the accumulation of operating experience with these design improvements. To implement these suggestions and, also, to reduce the total dollar capital-cost commitments involved in new ventures, I believe insufficient emphasis was given to finding ways to stimulate more widespread use of smaller scale prototype reactors alone, using much existing turbogenerator equipment by locating the reactor alongside a powerplant now in operation, and with turbogenerating equipment of pressure and temperature levels which lend themselves to an atomic-energy trial run. In this concept of a reactor project, existing conventional steam-generation facilities would be retained so as to have the plant operable when the nuclear steam-generator is not operating. This kind of developmental reactor project might enable a utility to minimize total dollar capital costs and maximize operating experience and testing of the heat-energy potential of the reactor core design, or fuel element, under actual load conditions. This is the heart of our hook-on reactor program growing out of our evaluation of a proposed full-scale nuclear powerplant for a foreign program. (See my letter dated September 12, 1957, and attached report on GPU nuclear-power program, dated August 27, 1957.) We believe that if more utilities were encouraged and helped to consider such programs, wider participation by utilities in nuclear-power research and development activities might ensue and the time for developing commercial nuclear power might be shortened.

3. Our consideration of a specific foreign reactor installation in the Philippines convinces us that (1) a feasible foreign program must be pitched to the specific lacks and needs of a specific country whether in South America, a Euratom participant, or underdeveloped country elsewhere, concerning which State Department advice and coordination is most important; and (2) this country's foreign reactor-development program must give emphasis to (*a*) technological development, know-how, and operating experience and data; (*b*) supply of enriched fuel under favorable terms; (*c*) supply of reactor components and fuel-reprocessing services; (*d*) financing assistance; and (*e*) advice on reactor and power utilization techniques. In these respects, wider use of prototype-scale reactors of hook-on variety could contribute more to foreign reactors by accelerating the acquisition of design engineering or operating know-how and data more quickly than experimentation with more reactor types in full commercial scale. Furthermore, large-scale reactors, if unsuccessful, would not be repeated.

Meanwhile, this utility system plans to continue exploring the feasibility of its hook-on reactor program with equipment manufacturers and to discuss this program with the Commission as soon as we have potentially interesting developments to report.

Sincerely yours,

E. W. MOREHOUSE, *Vice President.*

GENERAL PUBLIC UTILITIES CORP.,
New York, N. Y., February 25, 1958.

Hon. CARL T. DURHAM,
Chairman, Joint Committee on Atomic Energy,
Congress of the United States, Washington, D. C.

DEAR CHAIRMAN DURHAM: This letter is submitted in response to your communication of January 20, 1958, inviting GPU to submit a statement in connection with the current section 202 hearings. This statement will bring up to date our previous letters, including the latest, dated September 12, 1957, reporting on our atomic-energy activities.

As previously reported, GPU owns in addition to domestic electric utility subsidiaries in Pennsylvania and New Jersey, the Manila Electric Co. in the Philippines. Because this foreign subsidiary uses fossil fuel costing about 1½ times the present highest level of fuel costs in our domestic system, and therefore could be expected to be the earliest place among our properties where a nuclear powerplant might be economically justifiable, our principal efforts up until the last few months were directed toward determining the feasibility of installing a nuclear powerplant on the Manila system. Following preliminary studies and discussion with equipment manufacturers, we invited proposals for the installation of a 60 electric megawatt nuclear power plant in Manila. During the year just past, GPU completed an evaluation to the extent considered necessary of the two proposals which we received, both for water-type reactors. As explained in more detail in our letter of September 12, 1957, and accompanying report, we concluded that acceptance of either proposal received could not possibly be economically feasible. Not only was capital investment for a nuclear powerplant at least three times that for a conventional fuel plant in Manila, but no immediate savings in fuel costs were expected to be realized and possible fuel cost savings in the next decade from the use of nuclear fuel were insufficient in amount and to conjectural to make the project at all feasible.

As a result of our evaluation study of the Manila nuclear powerplant proposal, we have reexamined and refocused our thinking with respect to our participation in the development of nuclear power technology.

While we have concluded that the Manila project is not feasible at the present time, we share the conviction of others that there are promising long-run prospects for technical improvements and cost reductions in water-type reactors. These improvements and cost reductions seem to us most likely to come about in the next few years through simplification in design and equipment, through increases in heat output, and through fuel use and handling economies. We believe these will in turn be made possible in large measure through actual operating experience, and the water-type reactor is the earliest type likely to afford such experience.

Therefore, we have during the last few months been exploring in detail with equipment manufacturers the feasibility of adding a small water-type nuclear reactor at our Saxton, Pa., power station, and of hooking on the reactor to the existing steam turbogenerators. The hookon concept has the immediate advantage of reducing total investment by eliminating the need of purchasing new electrical generating equipment. It also has the advantage that continuity of station operation can be maintained through the use of existing steam generating facilities whenever it becomes necessary or desirable to shut down the nuclear reactor. We will not have to place the same emphasis on continuity of operations of the reactor that would be necessary in a large-scale nuclear plant. Also, we believe that it should be possible to keep our reactor and auxiliary equipment to a minimum and within a practical cost range. By limiting the size and scale of investment so that the hookon reactor can be considered as an experimental and expendable plant devoted to the development of the art, we can afford to push it to the limits of performance consistent with safe operations, and in this way should be able in a relatively short time to obtain data which will be important in the design of new reactors as well as in the operation of large plants already under construction.

This approach to the development of atomic power has a number of attractive features. Some of these are:

1. It is dedicated primarily to the advancement of the art and not at the generation of large quantities of energy.

2. It provides a means whereby a utility can make an early contribution to reactor development and at the same time gain valuable practical experience for itself as well as others.

3. It concentrates on the stepwise development of the water reactor through actual experience, and is aimed at the determination of the capability of this type of reactor, primarily by exploring potential improvements in reducing fuel costs.

4. It provides a versatile and flexible facility available for determining, under actual operating conditions, performance limitations.

While GPU and its subsidiaries will gain valuable experience in the operation, maintenance, and the general problems of designing and building a nuclear reactor, the project would also contribute to reactor development. GPU necessarily looks to the reactor designer and manufacturer for technical ideas and judgments about the details of reactor design and operation and about the contribution which the project can be expected to make to reactor technology. Therefore GPU considers it essential that a competent reactor designer and manufacturer be found who regards the project as an important and integral part of his own plans for the development of the art and who will agree to participate technically and financially in the project on a joint basis.

GPU's detailed exploration of this project with several manufacturers is continuing, but it will be some months before these investigations are concluded, and we can determine whether or not the project will justify the substantial financial commitment which would be required of GPU. If the GPU management succeeds in its present efforts to develop a worthwhile project, we shall promptly submit it to our board of directors for consideration. We have already advised our board that while we are not yet in a position to submit firm estimates to them for either capital or operating expenses, it is hoped that when negotiations are completed, the financial dimensions of the capital investment in GPU's share of the program will be below $8 million spread over several years. We have also advised our board that we regard the $8 million ceiling figure as bearing a reasonable relationship to our capital structure.

As in the past, we will keep the joint committee advised of developments in our plans.

Sincerely yours,

E. W. MOREHOUSE.

GENERAL PUBLIC UTILITIES CORP.,
New York, N. Y., September 12, 1957.

Hon. CARL T. DURHAM,
Chairman, Joint Committee on Atomic Energy,
Washington, D. C.

DEAR CHAIRMAN DURHAM: We have now concluded our study of the economic feasibility of installing a full-scale nuclear powerplant on the system of our Philippine subsidiary, the Manila Electric Co., and we are writing to report our conclusions to you. We also wish to advise you of our present thinking regarding possible construction of an experimental smaller scale reactor plant in our domestic system.

GPU began its study of the economic feasibility of installing a nuclear powerplant in Manila in the late summer of 1955 following issuance to GPU of an access permit for this purpose. We selected the Philippine location rather than GPU's domestic system in Pennsylvania and New Jersey because of the relatively high cost of conventional fuel in the Philippines. Following preliminary study and informal consultations with several equipment manufacturers, we requested bids early in 1956 for the fabrication of a 60,000-kilowatt (electric) nuclear plant for Manila. Proposals were received from the manufacturers in the summer of 1956, both based on a pressurized water-type reactor.

The results of our evaluation of the manufacturers' proposals are summarized in a report to the GPU board of directors, a copy of which is attached. This report concludes that the cost of nuclear power would be so much higher than the cost of conventional power in the Philippines that the installation of a nuclear powerplant in that country is not economically feasible at the present time.

As indicated in the report, the capital cost of a 60,000-kilowatt nuclear plant is estimated at a minimum of $600 per kilowatt of electrical capacity, or more than twice the capital cost of a comparable conventional plant. Fuel costs during the initial period of operation are estimated to be in the range of 6.1 to 8.5 mills per kilowatt-hour, i. e., approximately the same as the present cost of oil fuel now used by the Manila Co. Although our estimates anticipate that there will be a substantial reduction in nuclear fuel costs as a result of improvements in fuel

technology during the life of the reactor, and that there might, therefore, be future savings in fuel costs compared with a conventional plant, we see no prospect that such savings would be large enough to offset more than a fraction of the extra investment in a nuclear powerplant.

The above cost estimates are believed to be minimum figures, which are based in some instances on preliminary data in areas where no experience is available and upon assumptions which basically favor a nuclear powerplant. If the committee wishes to have a more detailed explanation of our figures, we will be happy to make available to you or your staff our technical personnel and engineering consultants and to go over the engineering reports and estimates which are summarized in the attached report.

In reporting our conclusion that installation of a nuclear plant in Manila is not feasible at the present time, we also desire to acquaint the committee with the direction of our thinking in respect to future work. From a utility system point of view based on our evaluation studies, the principal obstacles to nuclear power generation are the high present investment and operating costs and the lack of demonstrated reliability. We believe, however, that there is sufficient long-run prospect for technical improvements and cost reductions in reactors to justify our continued interest and possible participation in the development of nuclear powerplant. Such improvements and cost reductions seem most likely, on the basis of present information, to come about in the next few years through simplifications in design and equipment, and through increases in heat output and core efficiency. We presently believe that there is a good chance that improvements and economies of these kinds can be made in a water-type reactor, which is probably the earliest type likely to afford actual operating experience. We think they can best be accomplished through the actual construction and use of nuclear steam plants under utility operating conditions at an existing steam power station, under conditions where we can push the reactor to the limit of performance consistent with safety requirements. At the same time we feel that the way for us to proceed at this time is through a small plant involving a minimum of investment whcih can be operated on a frankly experimental basis. The objective would be to determine the maximum capability of such a plant and to learn how to design, build, and operate economically attractive large-scale plants.

With these objectives in mind, we have discussed the matter with the GPU board of directors which has indicated that it feels that the feasibility of this approach should be carefully investigated. Accordingly, we plan immediately to explore in detail with equipment manufacturers the feasibility of adding a small water-type nuclear reactor at our Saxton, Pa., power station and of hooking on the reactor to the existing steam turbogenerators. The hook-on concept has the immediate advantage of reducing total investment by eliminating the need for purchasing new electrical generating equipment. It also has the advantage that continuity of station operation can be maintained through the use of existing steam-generating facilities whenever it becomes necessary or desirable to shut down the nuclear reactor. With this approach we will not have to place the same emphasis on continuity of operation that would be necessary in a large-scale nuclear powerplant. We can keep our reactor and auxiliary equipment to a minimum and we can afford to push the reactor to the limit of performance consistent with safety of operations. In this way we should obtain in a relatively short time data which will be important in the design of new reactors as well as in the operation of large plants already under construction.

In approving an exploration of the feasibility of this hookon reactor program, the GPU board of directors has not acted on the ultimate question whether, in the particular circumstances applicable to the GPU system, it is appropriate and feasible to proceed with the project. After we have had an opportunity to discuss plans with the equipment manufacturers as well as the representatives of AEC and have determined more precisely the investment and operating costs and benefits involved in the hookon reactor program, we plan to present the matter again to the board of directors for its consideration.

We will, of course, keep your committee advised as to developments in our plans for the hookon reactor.

Sincerely yours,

E. W. MOREHOUSE, *Vice President.*

GENERAL PUBLIC UTILITIES CORP.,
New York, N. Y., March 2, 1956.

HON. CLINTON P. ANDERSON,
Chairman, Congressional Joint Committee on Atomic Energy,
Washington, D. C.

DEAR SENATOR ANDERSON: We appreciate the opportunity afforded by your letter of February 17 to comment on the report of the panel on the impact of the peaceful uses of atomic energy. At present the major activity of our company in the field of atomic energy centers in our interest in the construction of a nuclear powerplant in the Philippine Islands. Hence our comments are directed primarily to aspects of the report which have a bearing on our work in connection with a project in the Philippines.

General Public Utilities Corp. is the parent company of five electric utilities which operate in Pennsylavnia and New Jersey and it is also the parent of Manila Electric Co., a corporation organized in the Philippines, with operations in and around Manila.

GPU's activity in nuclear power goes back to 1949. In that year I was 1 of the 3 individuals requested by the AEC to serve on the ad hoc advisory committee on cooperation between the electric power industry and the AEC. The report of that committee was submitted to the AEC in 1951. Later when industry study teams were formed, GPU and some of its subsidiaries became members of what is now known as Atomic Power Development Associates. By early 1955 our work had developed to the point where we felt that, in addition to our participation in APDA, the GPU group should also undertake a separate study of the feasibility of installing a nuclear powerplant on one of our own operating systems. It was clear that from the standpoint of economic feasibility, Manila Electric Co., which has high fuel costs as compared with our domestic operations, presented the most favorable opportunity for installing an atomic powerplant on our system at an early date. Conventional fuels used in the Philippines now costs about 55 cents per million B. t. u. as compared with fuel costs on our domestic system which vary from about 17 to 35 cents per million B. t. u. Therefore, in commencing our separate study last summer we concentrated from the first on the idea of an atomic powerplant in Manila. The substantial progress we have already made in this new effort is described below.

GPU and its predecessors have owned Manila Electric Co. for over 30 years. Since World War II, GPU's problems in managing Manila Electric Co. have been particularly acute. The Manila company suffered extensive damage, both during the Japanese occupation and the fighting which finally liberated the Philippines. After the war, GPU assisted the Manila company in prompt rehabilitation of its system and in successfully building up its capacity to supply the growing electrical load of the Manila area. Our problems in accomplishing this task and in planning for the future needs of the Manila area have been complicated by the fact that the Securities and Exchange Commission had found it necessary under the Public Utility Holding Company Act of 1935 to order GPU to dispose of its interest in Manila Electric Co. It has not been possible to comply with this divestment order and we do not believe there is a practical way to do so under present conditions without prejudice to the best interests of the Manila Electric Co., its Philippine consumers, and the GPU stockholders. This problem can only be cured by appropriate legislation and such legislation is under consideration. Meanwhile, because of the long lead time involved in planning and constructing new capacity, GPU has had to proceed with plans for meeting new load requirements in the Philippines. Conventional fossil fuel plants of Manila Electric Co. now under construction or authorized are expected to take care of needs through 1958. Recent engineering studies indicate that still further capacity will be required by it for 1959 or 1960 and our hope is this need can be met by a nuclear plant.

We have made substantial progress on the Manila nuclear power project. We have located a promising site; we have drawn up the specifications for a nuclear powerplant; and we have asked for bids on the manufacture of a nuclear power reactor. We should like to make it clear that our thinking with respect to this nuclear powerplant has been that it would be financed by private capital in a manner similar to a conventional fuel plant.

Preliminary investigation shows that a site not far from Manila and naturally isolated from populated areas, would be suitable for the project and could be readily integrated into the Manila electric system. During 1955 we had several preliminary meetings with a number of equipment manufacturers and in January 1956 we formally invited bids and proposals from 4 of the major equipment manufacturers for a nuclear steam generator with an electrical capacity of 60,000 kilowatts. The invitation requires that proposals be submitted by June 1, 1956.

Until proposals have been received and evaluated, we cannot tell whether or by what date it may prove economically feasible to construct a nuclear powerplant in the Philippines. Furthermore, while the proposals we receive will establish some of the major elements of the cost of a nuclear plant, there are other elements of cost which will have to be established before a decision can be reached to proceed with construction. Of these we consider the most troublesome to be the cost of return shipment and chemical reprocessing of irradiated fuel elements. We have begun discussions with private shipping interests about the cost of transporting irradiated fuel. At present, however, there are no private facilities capable of reprocessing nuclear fuel, and until such facilities are available we will have to rely on the AEC to do the reprocessing. We believe that determination by the AEC of conditions and prices which will govern this work is necessary before we can finally evaluate the project.

We recognize, of course, that a nuclear powerplant can be constructed by Manila Electric Co. only after an appropriate agreement for cooperation has been made between the United States and Philippine Governments. We have already had preliminary discussions with the Philippine Government and hope that negotiation of the agreement will take place at an early date.

Two recommendations contained in the panel report are of particular importance to us. One of these relates to the supply of nuclear fuel to foreign reactor projects. The other concerns declassification of reactor technology.

We were greatly encouraged by the panel's recommendation that the United States should "announce that it is prepared to furnish nuclear fuel * * * for the installation of at least 1 million kilowatts of atomic generating capacity outside the United States as soon as possible." The President's recent announcement of an allocation of 20,000 kilograms of U–235 for foreign reactor projects is another welcome step. As we understand the President's announcement and the companion announcement by the Chairman of the Atomic Energy Commission, material will be set aside for specific foreign reactor projects to meet their full fuel requirements during the life expectancy of such projects. The reactor types presently being considered for the Manila project are all expected to require an enriched uranium fuel and we regard long-term commitments by the United States Government for fuel supply as indispensable to the project. Without such commitments neither the recommendation of the panel nor the announcement of the President will be effective.

Two important unknowns are the price to be charged for fuel for foreign reactors and the amounts to be paid for plutonium or U–233 produced in them. We are hopeful that these prices will be fixed and announced in time to permit us to proceed with the evaluation of bids as soon as we receive them from the equipment manufacturers.

There are other conditions, also yet to be determined by the Government, which will affect the Manila project. Among these are restrictions on the level of fuel enrichment and requirements respecting return and reprocessing of spent fuel. We do not yet know whether or to what extent limiting the enrichment of fuel will affect the economics of our project, and we are not aware of any adequate technical and economic studies on the subject. We have asked the equipment manufacturers to include in their proposals designs based on optimum fuel enrichment as well as designs based on fuel enrichment not exceeding 20 percent. It is possible that it will prove more economical to use a natural uranium fuel seeded with highly enriched uranium than to use fuel elements with a more limited enrichment. We hope that any limitations on enrichment which may be established by the AEC will be flexible enough to permit adjustment to the economics of our project.

As to reprocessing of nuclear fuel, we do not expect that there will be facilities for this work in the Philippines for some years to come. We, therefore, have no objection to the panel's recommendation that foreign atomic powerplants be subject to interim control plans requiring return and reprocessing of spent fuel for recovery of plutonium or U–233 in the United States. The requirement ought to be flexible enough, however, to permit the storage of irradiated fuels in the Philippines during a cooling off period and to permit permanent disposal of spent fuel in the Philippines in the event that the cost of returning and reprocessing exceeds the value of the material to be recovered.

The second panel recommendation of special interest to us is the proposal that the AEC declassify all reactor technology, including fuel element fabrication and processing techniques, except information of military significance. We strongly favor this recommendation. Declassification will greatly facilitate the transmission of technical and cost information to the Philippines and will contribute to the feasibility of proceeding with the project. We are naturally concerned not only with information needed for the construction and initial operation, but also with subsequent advances in reactor technology which can contribute to safety, efficiency, and reliability of the plant. Manila Electric needs to be in a position to take advantage, for example, of new techniques in fuel fabrication or reprocessing that might reduce the cost of operation.

If your committee desires any additional information about our work in the atomic power field we will, of course, be glad to furnish it.

Sincerely,

E. W. MOREHOUSE, *Vice President.*

REPORT ON NUCLEAR POWER PROGRAM

General Public Utilities Corp., August 26, 1957

AUGUST 26, 1957.

To the board of directors of General Public Utilities Corp.
Re GPU's nuclear power program.

Since 1955 we have been engaged in an intensive study of the feasibility of installing a nuclear powerplant in the GPU system. This study has been conducted for the benefit of the entire GPU system and has involved participation by personnel of GPU and several of the subsidiaries, as well as by outside consultants retained for that purpose. At the outset it appeared clear that (*a*) the results of the study would be most worthwhile if they could be focused upon a specific project and (*b*) a nuclear generating plant offered the greatest possibility of feasibility if installed in the portion of the GPU system when fuel costs were highest, namely, Manila Electric Co.

Recent studies of the Manila Electric system had indicated that the optimum size of its next generating addition was 60 megawatts.[1] Therefore, specifications were issued to four equipment manufacturers that have been working in the nuclear power field and that have experience with the problems of servicing foreign power installations. These specifications invited such manufacturers to submit proposals for a 60-megawatt nuclear powerplant for installation on a selected site near Manila. Proposals were submitted by two manufacturers and these proposals have been exhaustively analyzed and the results compared with the data relating to a 60-megawatt conventional generating unit.

Since this study has been a joint system project for the benefit of the entire system and since the knowledge acquired has been pertinent to both GPU's domestic and foreign systems, even though focused upon a possible Manila Electric Co. plant, GPU has borne the costs of the study.

This report and its appendixes summarize the results of our studies and set forth our recommendations for the future course to be followed. Such appendixes consist of (1) Report of Feasibility Evaluation of a 60-Megawatt Nuclear Powerplant for the Manila Electric Co. System and (2) Summary Technical Specifications for a GPU Utility "Hookon" Reactor Program.

The evaluation report (appendix A) is based on the studies by Gilbert Associates, Inc. (GAI), power engineering consultants, as to the plant facilities and their estimated cost, and by Pickard-Warren-Lowe Associates (PWL), nuclear consultants, as to nuclear fuel costs. The proposed GPU utility "hookon" reactor program, set forth later in this memorandum, was developed in the light of the knowledge gained in the analysis of the proposed Manila nuclear plant. Through this reshaped program we believe the GPU system can make a useful and prompt contribution to nuclear technology for the benefit of its consumers and investors and of the electric utility industry as a whole.

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[1] All capacity and energy amounts in this report and appendixes are expressed in terms of net electrical output; similarly, all "per kilowatt" or "per kilowatt-hour" figures are based on net capacity or net energy.

GENERAL CONCLUSIONS AND RECOMMENDATIONS

1. A 60-megawatt nuclear powerplant as proposed by the two equipment manufacturers is not yet economically justified for Manila Electric Co. or for any other GPU operating company as an alternative to a conventional fuel plant of the same size. Because such a nuclear powerplant also is not likely to become economical without the improvement that will come from more experience in constructing and operating nuclear plants, we recommend that neither of the two proposals be accepted.

2. We also recommend that prompt action be taken looking toward the construction and operation of a nuclear powerplant in the GPU domestic system. We contemplate the continued participation in this project of GPU and its operating subsidiaries (including Manila Electric to the extent permitted by law). In appendix B we outline the summary technical specifications for this program, which is intended to (*a*) produce the maximum of knowledge and experience and (*b*) minimize the investment commitments. This program would utilize a smaller scale reactor, which can be installed adjacent to an existing GPU system steam-electric station so that it can be operated under actual load conditions to determine (*a*) the ultimate thermal capability and effective fuel use of the reactor, (*b*) its performance and reliability under variable load-carrying conditions, and (*c*) the minimum reactor investment required, while at the same time maintaining the operability of existing conventional fuel boilers and turbogenerators. One of the GPU domestic steam stations (at Saxton, about 20 miles south of Altoona, Pa.) appears well suited for this purpose, whereas Manila Electric Co. does not have such a station. We, therefore, recommend that this program be focused on the installation of such a reactor at the Saxton station (i. e., "hooked on" to its existing facilities).

BASES OF FOREGOING RECOMMENDATIONS

1. The foregoing recommendation with respect to the Manila nuclear power project is predicated upon the following chief factual conclusions, arrived at on the basis of the evaluation described in appendix A:

(*a*) The proposed 60-megawatt nuclear powerplant, installed on the Manila Electric Co. system at the Talim Island site and completed in 1961, would require a total initial expenditure of not less than $36 million or $600 per kilowatt installed.

A 60-megawatt conventional fuel unit installed at Rockwell station of Manila Electric Co. and completed in 1961 is estimated to cost $14.5 million ($242 per kilowatt). If this unit were installed as the first unit in a new location in 1961 the estimated cost would be about $16 million ($267 per kilowatt).

The minimum excess of investment in a 60-megawatt nuclear unit over that required for a conventional unit of similar capacity is approximately $21.5 million ($358 per kilowatt) if the conventional unit is to be in an existing station, and approximately $20 million ($333 per kilowatt) if the conventional unit is to be in a new location. In order for the nuclear plant to be economically competitive, it would have to achieve fuel savings sufficient to offset that excess.

The addition of an oil-fired superheater (a feature in the proposed nuclear powerplant of Consolidated Edison Co., of New York) would increase the effective capability of the plant to approximately 82.5 megawatts. Since such a superheater would involve an additional cost of only $2 million, it would result in a reduction of the unit investment cost to not less than $460 per kilowatt.

If consideration is given to the superheated nuclear plant, then the alternative conventional unit size used for purposes of comparison must also be increased. Such an increase involves a relatively low cost for the additional capacity; i. e., a conventional unit of approximately 82.5-megawatt capability would cost approximately $18 million ($218 per kilowatt in an existing station or approximately $19.6 million ($237 per kilowatt) in a new station. Consequently, the total dollar difference between the nuclear and conventional plant costs, which must be justified by nuclear fuel savings, remains in the neighborhood of $20 million.

With present fuel oil prices in Manila, the use of a superheater would not substantially reduce the composite cost of fuel per kilowatt-hour. Furthermore, with anticipated increases in the cost of oil and expected reductions in the cost of nuclear fuel, the composite cost of energy from the superheated nuclear plant can reasonably be expected to exceed the future cost per kilowatt-hour of straight nuclear fuel. In the long run, therefore, the superheater produces a smaller

margin of savings per kilowatt-hour to be applied as an offset to the additional investment of about $20 million.

The addition of a superheater to a 60-megawatt nuclear plant results in a larger unit than is presently best adapted to the Manila Electric system. On the other hand, the indications are that the cost of a superheaded nuclear plant with total capability of only 60 megawatts would be in excess of that for a straight nuclear plant of the same capacity.

For these reasons, our analysis of costs has been primarily directed to a comparison of those of a straight nuclear plant with those of a conventional plant.

(*b*) The estimate of nuclear fuel costs during the period of initial operation of the first reactor core (1961–63) ranges from 6.1 to 8.5 mills per kilowatt-hour (without including any provision for Philippine taxes on nuclear fuel, even though taxes constitute 25 percent of the present cost of oil in the Philippines). With subsequent reactor cores during a period several years after startup (1967-70) the estimated costs will range between 3.9 and 5.1 mills per kilowatt-hour (again without provision for a tax component). The estimated conventional fuel cost in 1961 is approximately 7 mills per kilowatt-hour, including a 1.75 mills tax component.

(*c*) The potential savings from use of nuclear fuel, assuming realization of the minimum figures for the 1967–70 period, are still not sufficiently large to support the higher fixed requirements applicable to the larger investment in a nuclear fuel-fired plant, even if a fixed charge rate sometimes used by FPC in economic studies under United States conditions for a conventional plant, namely, 11.7 percent were used.

Such a fixed charge rate is lower than that applicable to today's conditions, since it was developed some time ago and is pitched to a total capital cost which includes a bond interest component of only about 3 percent. It is furthermore much lower than that properly applicable to investments in the Philippines where higher levels of capital costs prevail. This overall 11.7 percent rate is also lower than that properly applicable to a nuclear powerplant which, in current designs and state of technological development, has a larger proportion of short-lived plant with higher depreciation rates than does a conventional fuel plant. The development of an appropriate fixed charge rate under these conditions is not necessary, since, even utilizing FPC's 11.7 percent rate and all other assumptions favorable to the nuclear plant, its costs are clearly outside the target area of economic feasibility.

Based on expected minimum fuel costs of the 1967–70 period and the assumption that there will be no tax component in the cost of nuclear fuel, the maximum annual fuel cost saving for a nuclear plant will be approximately $1,240,000 (7 mills per kilowatt-hour conventional fuel cost minus 3.9 mills per kilowatt-hour minimum nuclear fuel cost or 3.1 mills, multiplied by the maximum energy from a 60-megawatt unit usable in the Manila system, 400 million kilowatt-hours). This saving, capitalized on the basis of the too low 11.7 percent rate, would support an additional investment of $10.6 million in a nuclear power facility, which is only about half of the approximate excess of cost of the nuclear powerplant over the cost of a conventional plant. This striking comparison gives no weight to (1) the GAI estimate that total nuclear plant expenditure might exceed $36 million by "as much as 20 percent," (2) the fact that the potential reduction in nuclear fuel savings depends upon the anticipated—but not demonstrated—ability to achieve such savings, based upon future expectations, (3) the expected higher operation and maintenance expense (excluding fuel) for the nuclear plant, (4) the probably unrealistic assumption that there will not be a Philippine tax component in the cost of nuclear fuel, (5) the additional research and development, insurance, and personnel training costs associated with a nuclear plant, and (6) the fact that the 11.7 percent fixed charge rate employed is unquestionably on the low side.

(*d*) The evaluation study summarized in appendix A embraces a detailed analysis of the nuclear fuel cycle and the estimated costs applicable to each step in this cycle, as well as an investigation of plant costs. The latter investigation started with an exploration of potential sites for the plant and a selection of the best available site. The equipment manufacturers' proposals were found not to include all components of an operable powerplant, and therefore, additional data had to be procured for the estimates of all equipment essential to the operation of a full-scale plant. A preliminary plant layout on the site selected was made, as well as estimates of the manpower requirements and some of the operating and maintenance costs expected.

In the investigation and evaluation of the two proposals received, our consultants and the system personnel who were engaged in the evaluation work held several conferences with representatives of the equipment manufacturers. We received excellent cooperation from the manufacturers and upon completion of the preliminary figures we made such figures available to them for their review, criticisms, and comments. No revisions were suggested which would bring the proposals within reasonable prospect of economic feasibility.

2. Our recommendation for a reshaped program, calling for the installation of a skeletonized installation at Saxton, is based upon the following considerations:

(*a*) For the reasons set forth above, the installation of a nuclear powerplant in the GPU system cannot be economically justified at the present time, because the investment and production costs are too high. Moreover the reliability of a nuclear powerplant for utility system operation under load or where definitive costs are a prime consideration has not been demonstrated. Our reshaped program proposes to attack these problems directly.

We propose to attack the problem of total plant investment by (1) building a small plant and utilizing existing investment so far as feasible; and (2) deliberately keeping the purely nuclear plant facilities to the minimum consistent with safety of personnel and property. We propose to attack the problem of investment cost per kilowatt of output by pushing the plant step by step to the limit of its safe operating performance. In this way, we will minimize the investment in the "hook-on" project and at the same time we may be able to demonstrate that it is possible to get enough additional output per dollar of investment to bring the investment cost of nuclear powerplants down to the area of economic feasibility.

We also propose to attack the production cost problem by pushing the nuclear plant to the safe limit of its capability and using varying types of core loadings. In this way, we may be able to lower fuel inventories and to extend reactor core-lives, and thereby reduce the reprocessing and inventory costs per kilowatt-hour, which are such important components of the unit cost of nuclear fuel.

We propose to attack the problem of determining reliability of performance for utility purposes by operating our proposed nuclear plant under actual utility conditions and subject to the same demands that are imposed upon conventional generating stations.

(*b*) One important consideration in the suggestion that the reactor be installed in an existing generating plant, so as to reduce the initial investment cost, is the fact that, in the present stage of reactor technology, the heat energy output of the reactor is at relatively low temperatures compared with the best modern practice using conventional fuels. These relatively low temperature limitations contribute to the generally higher costs of nuclear power. The purchase of low-pressure turbine and accessory steam equipment in today's designs will show only minor improvements over equivalent apparatus built in the past. There is no need to make a new investment of this type when there is available in the Saxton Station well-maintained, reliable machinery of suitable characteristics.

(*c*) Our view that it may be possible to reduce investment costs by deliberately keeping the purely nuclear plant facilities to a minimum reflects the use we propose be made of the reactor and the role it is to play in GPU system operations. The continued availability of the conventional boilers at Saxton Station will mean that the station can continue to operate even if the reactor is out of service. Moreover, even if the entire station were not available for a short period, system operations ordinarily would not be impaired. Consequently, we can deliberately skeletonize the nuclear facilities—i. e., install the bare minimum consistent with safety considerations, instead of installing extra facilities designed to insure the continued availability of the reactor. Because of the lack of experience in the operation of nuclear powerplants, there is a general tendency to anticipate equipment failures all along the line and to overbuild in an effort to provide for such failures. We propose to start from the other end, so that we will install additional equipment only as a need therefor is demonstrated by actual experience.

(*d*) Our view that it may be possible to overcome the investment cost obstacle by getting greater output from the reactor than its design size would indicate is available has significant support. There are some indications that it may be possible to multiply the heat energy output of a present-day reactor as designed by a factor of 2 to 4, a prospect which we hope to demonstrate factually on the basis of experience derived in this "hook-on" program. The reactor

which we would propose to install in Saxton Station would have a nominal design capacity of roughly one-quarter of the capacity of the turbogenerators installed in the station. Thus, there will be electric facilities in the station, the use of which can determine directly whether the indicated increased heat output of the reactor can be achieved and sustained. For reasons stated above, we will be able to push the reactor to this limit of its safe operating capability without impairing system operations.

(*e*) We should like to stress that, even if we are completely successful in achieving the objectives of this program, we do not believe that the Saxton "hook-on" reactor will itself produce power economically competitive with that produced in conventional modern stations. In other words, even if we are able to find means through the nuclear installation at Saxton whereby (1) the cost of construction of a nuclear plant can be significantly reduced by getting substantially more output per dollar of investment; (2) the operating and fuel inventory costs of a nuclear plant can be reduced by substantially extending core-lives; and (3) such a nuclear reactor can be operated as a reliable heat producer for electric utility generating purposes, nevertheless there is no substantial prospect that the specific installation at Saxton will itself be an economic power producer.

On the other hand, if we are successful in achieving the objectives of our recommended project, the knowledge and information gained will be helpful to us in determining whether we can build a subsequent reactor which will be economically competitive and feasible for use in a utility system. The information gained through the Saxton installation will, of course, be beneficial not only to customers and to stockholders of the GPU system, but also to the industry as a whole.

By carrying out this project, GPU system personnel will have had the advantage of firsthand participation in the design, construction, operation, and improvement of a nuclear reactor, rather than attempting to keep abreast of nuclear technology solely through the study of the efforts of others.

In short, we have learned from the Manila reactor study not only that we cannot economically construct today a nuclear reactor of substantial size, but also the outlines of the basic problems which require solution if that economic obstacle is to be overcome. We, therefore, propose to seek the solution to those problems in the most direct fashion, but on a scale and in a manner which appears to us to offer the best reasonable prospect of developing those solutions with a minimum investment.

Whether, and to what extent, the Saxton nuclear installation might continue to be operated, will, of course, have to depend upon future developments. However, in recommending the Saxton project, we nevertheless recognize that there is a very substantial probability that the Saxton nuclear installation would only be operated for a relatively short period—that is, until we have gained the experience and knowledge which reasonably can be expected to be obtained therefrom.

(*f*) We propose, as set forth in appendix B, to limit the types of reactors considered to those using pressurized or boiling water. We are satisfied that these are the only types of reactors that are now sufficiently well developed for a prompt attack upon the three fundamental problems which have been outlined. Moreover, even though the evaluation study of the proposed Manila reactor showed it to be uneconomic, it also indicated that there appeared to be sufficient opportunity for reducing investment and operating costs along the lines indicated above to justify further development of this general type of reactor. Indeed, we believe that if considerations are limited to the next decade, the water type of reactor offers as good, if not better, prospects for producing economic nuclear power than any other type. Moreover, it is quite likely that, if the water-type reactor is not the preferred type in the future, most of the experience and know-how obtained from conduct of this project will still be useful.

(*g*) It is hoped and believed that construction and operation of a reactor of the size and character discussed above, which is not burdened by the added expense of the electric generating facilities or the need for reasonably continuous operation, can be budgeted so as to keep both capital expenditures and operating expenditures under practical control and within reasonable bounds. In this connection, based upon our experience in connection with the two proposals submitted for the Manila nuclear powerplant, we believe that we can secure from equipment manufacturers firm prices for a nuclear steam generator and associated equipment of a water-type reactor.

(*h*) We believe that our project should attract interest from both the AEC and equipment manufacturers, for GPU's objective is the same as their objectives, i. e., to bring the cost of nuclear power down to an economic level. GPU necessarily approaches this project from the standpoint of an operating utility, concentrating on operating and maintenance characteristics and on investment and production costs, while the AEC and the equipment manufacturers will view the "hook-on" project as a facility in which a great deal can be learned about heat output, core life and equipment requirements. Because the Saxton "hook-on" reactor, unlike large reactors involving heavy investments, can be less conservatively designed and can be pushed to the safe limit of performance, even at the risk of a reactor outage, data can be obtained in a relatively short time which will be important in the design of new reactors and in the operation of the large plants already under construction.

At this point we are not seeking Board approval, but rather an expression of opinion as to whether we ought to proceed with development of such a reactor program and negotiation with equipment manufacturers. Later we would come to the Board with a definite expenditure program and budget. At this time no firm estimates can be given for either capital or operating expenses. It is hoped that, when negotiations are completed, the financial dimensions of the capital investment program will be below $8 million, spread over several years, a figure we regard as bearing a reasonable relationship to our capital structure.

E. W. MOREHOUSE,
Vice President.

APPENDIX A. REPORT OF FEASIBILITY EVALUATION OF A 60 MEGAWATT NUCLEAR POWERPLANT FOR MANILA ELECTRIC CO. SYSTEM

INITIATION OF PROJECT

This project was conceived and initiated in 1955. In the spring of that year, those in the GPU system who had been following developments in nuclear fuel technology since its early stages believed we were approaching the time when, in planning for future power capacity additions, consideration might be given to nuclear powerplants as alternatives to conventional fuel plants. The Atomic Energy Act of 1954 had opened the door to development of nuclear power and use of nuclear fuels by private industry. The AEC had formulated in 1954 the first stage of its civilian power reactor program and the Navy had given preliminary acceptance to the design for the nuclear-propelled submarine *Nautilus*. Many industrial concerns were vigorously seeking various ways to participate in this development program; and articles, talks, or statements by industry representatives were being issued that were highly optimistic as to the potentialities of nuclear energy and its early competition with fossil-fuel power.

Our observations of these developments in nuclear fuel technology, through participation in APDA and otherwise, had convinced us that progress in competitive utilization of nuclear fuel would proceed along certain lines highlighted in the following statements.

(1) Nuclear fuel held promise as a substitute for fossil fuels only if it enabled substantial reductions to be made in fuel expense. As in previous technological developments, the early plant facilities to use this new, radioactive fuel would clearly cost more than conventional fuel plant facilities, and hence higher fixed charges on the larger investments would eat up the savings in fuel expense unless those fuel cost savings were substantial.

(2) The earliest opportunities for making nuclear power competitive with conventional fuel power would arise where conventional fuel costs were highest.

(3) As with the development of electric power technology, research and development work would be, and should be, undertaken primarily by personnel of the equipment manufacturers rather than of regulated electric utilities.

In keeping with this general approach, it was believed that the Manila Electric Co. system should be the portion of the GPU system, where the earliest opportunity would arise to test the technical and economic feasibility of a nuclear powerplant. In 1955 the cost of oil to Manila Electric Co. was about 55 cents per million B. t. u.'s, whereas the highest cost of fuel on the domestic system of GPU at that time was approximately 36 cents per million B. t. u.'s. Manila Electric Co. was the fastest growing part of the GPU system. Gilbert Associates, Inc., was just completing for Manila Electric a long-range (1956 to 1965) study of load growth and power-supply requirements. This indicated that substantial increments in power capacity, in addition to those already planned or contem-

plated by the company and National Power Corp., would be needed from 1960 on and that the Manila Electric Co. could effectively utilize a nuclear powerplant if it proved feasible. Accordingly, it was decided to compare a nuclear powerplant with a conventional fuel plant by inviting equipment manufacturers to submit proposals for a 60-megawatt plant for installation as soon as practicable after 1960.

Specifications were prepared in the fall of 1955 by Gilbert Associates, retained by GPU as power-engineering consultants, in cooperation with Pickard-Warren-Lowe Associates, retained by GPU as nuclear consultants. They were issued under date of January 10, 1956. They called for submission of proposals for a nuclear steam generating plant alone (basis No. 1) or, in addition, a complete nuclear steam-electric generating plant (basis No. 2). Because (1) the location of the proposed plant was in a foreign country, (2) the nuclear portion of the plant was a new technology, and (3) servicing in the event of equipment failures was of prime importance to an isolated electric utility system, it was decided to invite proposals only from the four major equipment manufacturers with whom Manila Electric had dealt in the past with respect to conventional generating equipment and who had considerable experience with foreign installations and servicing requirements in the event of equipment failure.

Of the 4 invitees, 2 submitted proposals. The other 2 stated that they were not in a position to submit proposals at the time.

Both proposals submitted were for pressurized-water reactors. One proposal, on basis No. 1, was for a nuclear steam generator only. The other, on basis No. 2, was for an almost complete nuclear electric powerplant, including the turbine and electric equipment which the manufacturer considered appropriate for the temperatures, pressures, and other steam conditions adapted to the proposed nuclear steam generator.

SUMMARY OF FINDINGS AND CONCLUSIONS

1. *Overall conclusions*

Neither manufacturer's proposal for Manila should be accepted. Our major reasons for this conclusion are stated in the various paragraphs of this summary of findings and conclusions. They are expressed, in capsule form, in the following statements:

(1) Nuclear powerplant investment costs for a full-scale plant are higher than convential fuel-plant costs by a factor of 2 to 3. This applies not only for a construction period of the next 5 years, but probably applies, though in smaller proportions, to the next 2 or 3 generations of reactors, depending on how rapidly fabrication, construction, and operating experience and know-how, as well as nuclear design and applications engineering, can be developed and applied.

(2) Nuclear fuel technology in its present early stages results in a heat or steam cycle with a low thermal efficiency relative to present-day best practice in the use of fossil fuels for electric power production. This requires use of thermally inefficient steam-turbine and associated equipment, in terms of steam pressures and temperatures, that reflects the thermal technology in electric power production of 2 or 3 decades ago.

(3) In Manila, at any rate, the installation of a superheater fired with conventional fuel does not appear to offer reasonable long-run prospects of success when viewed as a component of a composite nuclear and oil-fired plant.

(4) Estimated nuclear fuel costs in the first reactor core are higher than present conventional fuel costs in Manila and, in the presently foreseeable cores of the period 1967–70, are *not lower by a sufficient margin* to support more than a small proportion of the added incremental investment of a nuclear powerplant.

(5) The probable total nuclear fuel costs are estimated to range between 6.1 and 8.5 mills per kilowatt-hour in the first core and between 3.9 and 5.1 mills per kilowatt-hour in a future core in the period 1967–70. These estimates, expressed in terms of mills per kilowatt-hour for an annual output of 400 million kilowatt-hours from a 60-megawatt plant, make no allowance for any taxes which may be imposed on nuclear fuel by the Philippine Government, and are predicated upon (*a*) AEC prices for fresh, slightly enriched fuel, (*b*) the present lowest attainable or reasonably foreseeable prices for fabricated fuel elements and assemblies, (*c*) the highest rates of fuel burnup in operation deemed reasonable from operating experience or forecasts to date, (*d*) AEC prices for reprocessing partly spent fuel elements, (*e*) lowest present estimates for waste disposal and losses in the fuel cycle, and (*f*) most reasonable present estimate of credits for plutonium recovery, fission byproducts and scrap recovery.

(6) We conclude from examination of the major components of nuclear fuel and related costs, highlighted below, that prospects over the next dozen years of reducing them sufficiently below fossil fuel costs as to bring a Manila nuclear plant within reasonable economic reach, are not promising.

(*a*) The nuclear project involves an extremely complicated fuel cycle, each step in this cycle involving costs that are made necessary by the inherent nature of the fuel. (See fuel-flow diagram in sec. B (1)).

(*b*) More than half the total nuclear fuel costs consist of the cost of (1) processing fresh fuel and fabricating it into fuel elements for the reactor core and (2) reprocessing spent fuel. Only the first of these components seems to have a reasonable expectation of being halved in the next decade.

(*c*) Another important element of nuclear fuel costs is the cost of fuel burned, after allowing (1) credit for returned fuel after reprocessing and (2) credit for plutonium produced in the fission process and sold to the United States Government. This cost does not have good prospects of substantial reductions in the next decade.

(*d*) A further large component of nuclear-fuel costs is the inventory charge on average inventory investment for the 2 proposals of $8.4 to $8.9 million. With the largest portion of this inventory tied up in the reactor core and spare fuel elements for the estimated core-lives and with nearly half the inventory value tied up in various steps in the fuel cycle involved in both cold processing fresh fuel and hot processing spent fuel, substantial economies in this area seem unlikely *except* by waiver of inventory charges (4 percent in United States and an assumed 6 percent in the Philippines or in transit). The chances of such waiver seem to be not a good business risk at this time.

(*e*) There are a great many uncertainties related not only to core design and performance but also to other factors affecting fuel costs, such as hazard protection costs and costs affected by corrosion rates and radiation contamination. Until operating experience is gained, prudence requires that these uncertainties be provided for by substantial allowances for contingencies in fuel-cost estimates, much greater than for a conventional fuel.

(*f*) A considerable amount of research and development work needs to be done on both core design and operating performance, both preceding operation and following startup. These costs have not been fully provided for in the estimates. Such costs will probably fall upon the purchaser of the reactor.

(7) In addition to these factors contributing to the relatively high level of production costs when using nuclear fuel, there are some factors which accentuate the relatively higher costs of nuclear powerplant and equipment than for a counterpart using convention fuel. Although some of these cost disparities may be expected to diminish as the gap between first costs of nuclear and conventional fuel-plant facilities and equipment is narrowed in the future, at present they contribute to the higher costs of nuclear power; and once the investment is made, these cost disparities become built into the cost structure of the nuclear powerplant.

(*a*) The nature of the equipment required in operating safely and reliably with nuclear fuel imposes some special investment or operating cost penalties as compared with conventional fuel-plant facilities and equipment. For example, the pressure vessel housing the reactor core, the containment vessel for the reactor portion of the plant, and the more complicated fuel handling and waste disposal systems are features of the nuclear powerplant not matched (or offset) in the conventional fuel plant. Such investment cost differentials are compounded when consideration is given to the amounts and higher costs of quality metals required in some of these unique features of a nuclear powerplant. The nature of such nuclear-plant facilities and equipment and the need for locating the plant away from densely populated areas also impose some special cost penalties, particularly including the categories of transportation, field construction costs, and import tariffs.

(*b*) The total *dollar* fixed charges for depreciation, taxes, interest or returns (dividends), and insurance are higher for a nuclear plant than for a conventional plant even though the overall *rates* of fixed charges would not differ materially, except with respect to depreciation and perhaps insurance. The higher total fixed charges arise largely from the larger capital investment required for a nuclear plant; and this cost differential obviously would diminish as the investment differential is reduced in the future. The nuclear plant, however, partly because of the nature of the fuel handled in

it, has a greater proportion of functionally short-lived equipment requiring higher depreciation rates than for conventional fuel plant equipment. This component of a fixed charge rate may be expected to diminish somewhat as more experience is gained over the life of the plant, but some differential of this nature seems likely to endure for some time to come.

(*c*) Capital costs generally are higher in the Philippines than in the United States, partly because of the demand and supply situation in Philippine capital markets, and also because of the belief held by capital suppliers from abroad that uncertainties attach to foreign capital investments in the Philippines. This situation is also affected by the regulations and limitations upon dollar remittances, not only to pay for equipment but also to pay interest and dividends, which were made effective by the Philippine Government in 1949 in order to conserve the Philippine international dollar reserves. The *rate* of capital costs, however, would not differ materially as between a nuclear and a conventional fuel plant in the Philippines. The *dollar* amount of such debt or equity capital costs and related taxes on income would be greater for a nuclear plant than for a conventional fuel plant because of the investment cost differential.

In one respect, however, capital costs in the Philippines have risen since the Manila nuclear project was begun. In 1956 the Philippine Central Bank issued regulations limiting the remittance of dollars of dividend payments. As a result, the earnings required to compensate American investors of new equity capital in the Philippines have risen sharply. This magnifies in the Philippines the economic penalty of the much higher plant investment required at the present time for a nuclear installation as compared with a conventional fuel plant.

2. Detailed conclusions

A. *Suitability of the pressurized water reactor.*—Both proposals were for a pressurized, light water-cooled and moderated reactor. More research and development effort has been spent on this reactor type than on any other type suitable for construction today. The development work on this type reactor by the equipment manufacturers making these proposals has been particularly outstanding. Furthermore, extensive development programs on this type of reactor are currently underway, so that considerable experience is expected to be obtained in time to be of benefit to near-term nuclear projects. Hence the choice of the pressurized water reactor for the Manila plant appears appropriate, not only to obtain a plant with as advanced technology as possible at this time, but also to consider a plant whose costs and performance can be predicted with as little uncertainty as possible.

While the estimated costs of designing and building the Manila nuclear powerplant are considerably in excess of the anticipated costs of building a conventional fuel powerplant, these costs appear to be in line with those experienced on other current reactor projects. Such high costs reflect the fact that the reactor as a source of heat energy is still in an early developmental stage; and it is believed that these costs will probably remain high for the next few years. Cost data to date are based to a large degree on incomplete experience with the pressurized water reactor at Shippingport, which plant is not yet in operation but is scheduled to come into operation late in 1957. Hence, it is not likely that experience from the Shippingport pressurized water reactor plant will become effective in reducing such costs with regard to the Manila project, on the basis of present proposals. Actually, recent announcements indicate Shippingport costs will exceed previous estimates.

In recent months it has increasingly been noted that the equipment suppliers on some other current nuclear projects have underestimated the difficulty of satisfying reactor requirements and hence have, either knowingly or unknowingly, supplied equipment at prices less than their true cost. Since this practice will probably not continue, some capital costs on second and third generation reactors may be higher than on the first.

It is believed that the prices quoted in both proposals made for the Manila project are realistic and do not contain any sizable support in the form of contributed research and development costs. In view of the large naval reactor program and other projects which are underway in the laboratories and shops of the two manufacturers submitting proposals for the Manila project, it would not be reasonable to expect them to make contributions to new full-scale projects such as the Manila unit. It may be reasonably expected, however, that with the passage of time and accumulation of experience and application of engi-

neering and manufacturing know-how, much more detailed cost estimates and, consequently, lower bid proposals for both reactor equipment and the fuel element supply and fabrication will be possible.

The reactor designs offered in both proposals are as reasonably thorough as present circumstances warrant. Examination of the data submitted in support of the proposals sustains the manufacturers' opinion that both plants could be constructed and would perform generally as indicated. Basic core design data and computational methods used by both manufacturers are similar and as consistent with each other and those used by other manufacturers of such equipment as is to be expected.

Additional design efforts, testing and development work would be required on both reactors proposed for the Manila project, primarily to determine the core specifications and expected operating performance. This additional design, testing, and development work is required because no industrial pressurized water reactor has been designed and built of a size comparable to that proposed for the Manila project, using stainless-steel-clad uranium-dioxide fuel elements.

B. ***Nuclear fuel and related problems.—***

(1) Nuclear fuel costs: Estimates have been made of the nuclear fuel costs for the proposed Manila plant both for the initial (first core) and future (5 to 7 years after startup) operation. Table I gives a general summary of the minimum and maximum costs for the two periods considered, expressed in terms of mills per kilowatt-hour. As indicated, total nuclear fuel costs in the period of initial operation (1961–63) are expected to fall within the range of 6.1 to 8.5 mills per kilowatt-hour. In the future operating period (1967–70) total nuclear costs are expected to range between 3.9 mills and 5.1 mills per kilowatt-hour. These nuclear fuel costs compare with conventional fuel costs, including taxes applicable thereto, estimated at 7 mills per kilowatt-hour in both periods.

TABLE I.—*Estimated fuel costs for Manila project*

[In mills per kilowatt-hour]

	Initial operation (1961–63)	Future operation (1967–70)
Estimated nuclear fuel costs:		
Fresh fuel processing and fabricating	2.8–4.7	1.2–2.0
Fuel burn-up (less plutonium credit)	1.0–1.8	1.0–1.5
Spent fuel processing and waste disposal	0.8–1.2	0.6–0.9
Inventory charge	1.1–1.3	.8–1.0
Total	5.7–9.0	3.6–5.4
Total probable nuclear fuel costs	6.1–8.5	3.9–5.1
Estimated conventional fuel costs:		
Conventional fuel cost (less tax)	5.25	5.25
Conventional fuel tax	1.75	1.75
Total conventional fuel costs	7.0	7.0

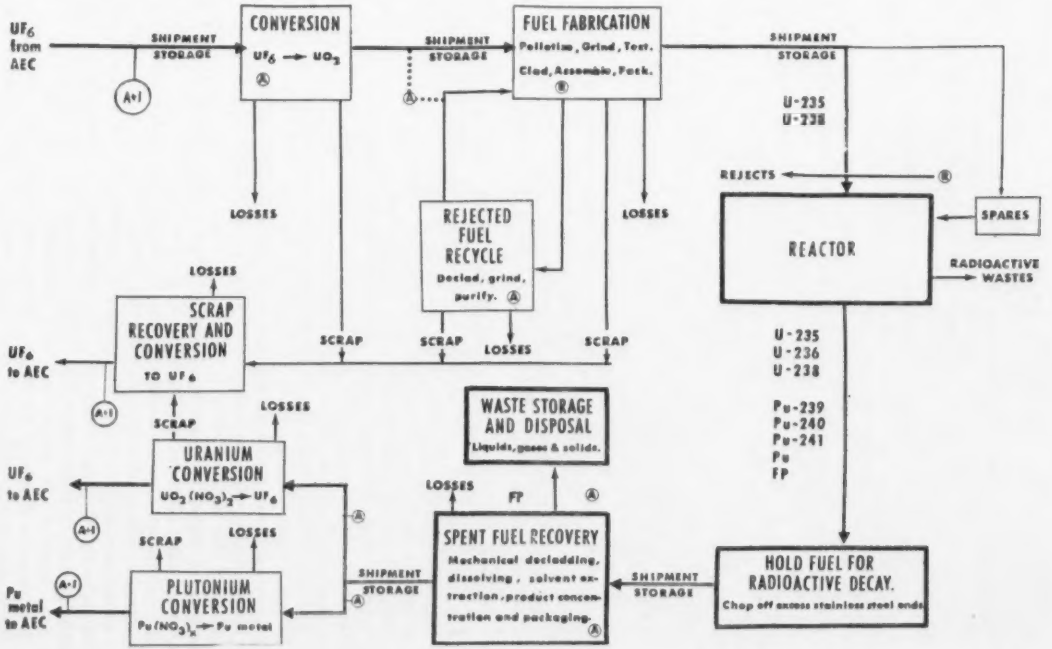
In estimating the conventional fuel costs in the table, it has been assumed that the price of oil will increase until 1961 at the rate of 2 percent per year from its present value, and therefore will remain constant, recognizing the impact after 1961 of different annual plant loadings, changes in import and other taxes, an increase in Philippine oil refining activities and the possibility of the discovery of oil in the Philippines. These conventional fuel costs are based on analysis by our power engineering consultants of a 60 megawatt conventional fuel plant designed for 1,800 pound per square inch gage, 1,000° F./1,000° F. reheat installed on the Manila system and completed in 1961.

The conventional fuel cost now has a tax component, including import, excise and other taxes, constituting 25 percent of the total cost. No similar tax component has been estimated for the nuclear fuel, although it is believed likely some such taxes may be imposed.

Listed below are the more significant assumptions made in calculating the estimated nuclear fuel costs (see fuel flow diagram):

Fuel Flow Diagram

Ⓐ = chemical assay; Ⓘ = isotopic analysis; Ⓡ = reactivity test; FP-fission products



(*a*) The core size, enrichment, and performance are assumed to be those proposed by the manufacturer.

(*b*) Regarding fresh fuel processing, one manufacturer offered a fixed price for a completed core assembly including all handling, conversion, fabricating, testing, and scrap treatment costs and this price was used. In the other proposal, the manufacturer offered only to fabricate the core from UO_2 supplied by Manila Electric, and the additional cost of supplying UO_2, treating scrap, etc., was calculated on information obtained from chemical processing companies, the AEC, the equipment manufacturer submitting the proposal, and others. Prices for estimating purposes have been obtained for processing specific amounts of material in many of the fresh and spent fuel processing operations. The estimates for these operations are believed to be reasonably reliable if processing were required in the near future and if the fuel requirements of the reactor are those predicted. Scrap rates in fresh fuel processing have been assumed at about 20 percent. This is lower than has been experienced to date.

(*c*) An annual energy production of 400 million kilowatt-hours was assumed, together with heat rates calculated by the power engineering consultants and reported in section C (5).

(*d*) The cost of uranium and the price of plutonium were assumed to be those in the latest AEC price schedules as applied to foreign plants. Under current United States policy, enriched nuclear fuels would be sold (or possibly leased) to the Philippine Government. The material would then be leased (or released) by the Philippine Government to the Manila Electric Co. For purposes of our estimates we have assumed that the material would be sold to the Philippine Government and that title would be transferred to the Philippine Government when the material actually left the United States.

(*e*) The annual lease charges were assumed to be 4 percent of the material value when the material was located in the United States, and 6 percent when in overseas transit or located in the Philippines.

(*f*) The cost of material consumed and the credit for material produced were estimated on the assumption that they would be paid or credited on a monthly or current basis and the lease charges were adjusted accordingly. This assumption favors the nuclear plant; but it has not yet been determined whether this monthly payment and credit procedure can and will be adopted by AEC.

(*g*) The radio-chemical processing costs were based on the AEC prices for such services. The AEC announced policy and price schedule for processing radioactive materials does not include the cost of converting the recovered uranium to UF_6. This item was assumed to be approximately 20 percent of the announced price of spent fuel processing.

The following comments apply to these assumptions:

The costs of processing the fresh and spent fuel, shown in table I, account for more than half of the total nuclear fuel costs. These costs depend directly on the core life and also on the form, composition, and weight of the core. Because of the uncertain nature of the core design and performance, the accuracy of such estimates of these costs is probably not better than plus or minus 35 percent. This is probably the largest uncertainty in the fuel calculations, and accounts for much of the range shown.

Another large uncertainty concerns the availability of the plant and the assumption that it will be capable of producing 400 million kilowatt-hours annually. Contrary to the assumptions, there is some likelihood that the plant will not average this production during the life of the first core, and, if so, the inventory component of fuel cost for the initial operation will be increased accordingly.

The relatively large range in the estimates of the cost of fuel burn-up and plutonium credit represents the inability to predict the core performance regarding fuel burned or consumed and plutonium produced over the rather long irradiations involved. These cost items also depend on the AEC price schedule for these materials. This schedule has been assumed to remain unchanged over the period involved.

These estimates of fuel costs are based in part upon the prices which would be paid for plutonium, as announced by the AEC on November 18, 1956. It was stated by the AEC that these prices were applicable to plutonium produced both in domestic and foreign reactors and that such prices were based upon the value

of plutonium for reactor fuel purposes. This announcement was made simultaneously with the President's announcement of the allocation of uranium for foreign reactors and that the United States would buy plutonium produced by such foreign reactors for use by the United States only for peaceful purposes. In May 1957, the AEC announced a new schedule of the prices which it will pay through June 30, 1963, for plutonium produced by domestic reactors. These prices are substantially in excess of those announced in November 1956 and it is apparent from the context of the announcements that the prices are based in part upon use of such plutonium in the weapons program. In its announcement concerning such new purchase prices for plutonium produced in domestic reactors, the AEC expressly stated that it was its expectation that the plutonium purchase prices applicable to periods after June 30, 1963, would be reduced to a value based upon the use of plutonium in commercial power reactors. Against this background, the May 1957 plutonium purchase prices for domestic projects have not been taken into account in determining the probable plutonium credit for the Manila reactor.

The future costs of nuclear fuel as given in table I have been estimated on the assumption that the largest cost reduction (50 percent) will be made in the fresh fuel processing item. This will probably occur as a result of increased production and improved fuel design. Other cost reductions are to be expected from reduced losses in many operations and by improved core performance. A 25 percent increase in core life has been assumed.

(2) Required research and development: Although the pressurized water reactor, as proposed for Manila, is technically the best understood type available for power generation, it is still under development. It is understood that both manufacturers have included provisions in their proposals for research and development. It is also noted that additional research and development costs beyond those included in the base proposals will be required prior to operation, primarily for additional core work, including the costs of supplying fuel for a critical assembly. These additional costs will probably be at least $1 to $2 million. Moreover, as noted previously, substantial fuel cost reductions are expected in the future. In view of this, a continuing research and development program aimed at minimizing the overall fuel costs is desirable. An annual expenditure of at least $100,000 would not be unreasonable and should be considered as includible in annual operating expenses.

(3) Insurance: Third-party liability insurance and protection against plant damage for coverage up to $50 to $60 million could probably be obtained for the Manila plant from the insurance associations recently organized in the United States. Additional coverage which may be available to domestic reactors through the United States Government will probably not be available to the Manila plant. For the purpose of estimating total project costs, it may be assumed that third-party liability for $50 to $60 million coverage would cost $70,000 to $100,000 annually. This rate is comparable to those to be charged the Elk River and Yankee plants. It may also be assumed that the property insurance rates for the Manila plant, also similar to the Elk River rate, would be about $75,000 annually.

(4) Personnel training: Because of the unique requirements for specially trained operation and maintenance personnel, rather thorough and long-range training programs should be instigated.

These important additional research and development, insurance and personnel training costs associated with a nuclear plant have been considered; but they have not been recognized in either the comparative plant or fuel costs, upon the basis of which the conclusions set forth in this report have been reached.

C. Nuclear plant costs: (1) Conclusions: As a result of studies made by our consulting power engineers, which are related to specified conditions established prior to or during the course of these studies, we have reached the following conclusions:

(*a*) Construction of the proposed 60-megawatt nuclear powerplant by Manila Electric Co., at the Talim Island site, with completion planned for 1961, will require a total expenditure of no less than $36 million or $600 per kilowatt. Because this estimate has been made on a minimum basis, the total cost may exceed $36 million by as much as 20 percent. At least 70 percent of the total cost must be paid in United States dollars.

(*b*) Construction of a 60-megawatt fossil fuel fired reheat unit by Manila Electric Co. at the Rockwell Station, with completion planned for 1961, will

require a total expenditure of $14.5 million or $242 per kilowatt. If such a unit were installed in an entirely new plant in 1961, its estimated cost would be $16 million. The required dollar payments for this conventional unit at Rockwell are also about 70 percent of the total cost.

(*c*) The addition of an oil-fired superheater to the nuclear plant at Talim Island would increase the output to 82.5 megawatts at a cost of approximately $2 million. Although the additional capacity is obtained at a relatively low cost, the overall plant cost would still be about $460 per kilowatt. This improvement in initial cost and possible savings in the composite fuel cost are not sufficient to make the modified nuclear plant attractive.

(*d*) The fuel cost of the conventional plant is estimated to be 7.0 mills per kilowatt-hour.

(*e*) The operation and maintenance costs, other than fuel, for the nuclear powerplant will be approximately 1.0 mill per kilowatt-hour as compared with 0.4 mill per kilowatt-hour for conventional plant.

(2) Plant site: Before specifications for the nuclear plant were issued, a preliminary search had been made for a suitable site in the Manila Electric system. The best site was found to be on Talim Island, in a fresh water lake known as Laguna De Bay. It is located about 20 miles from Manila and about 8 miles from the nearest point on Manila Electric's 115 kilovolt transmission system. The site is relatively isolated and the land is presently owned by the company, having previously been used in part for a quarry. Adequate condensing water is available.

No test borings or other underground investigations of the site were made, but available geological surveys and maps show that the area is in an earthquake zone. Further investigations of foundation conditions and earthquake hazards would be needed before final choice of the site could be made. It was considered adequate, however, for preliminary layout of the nuclear plant.

Although there were basic differences in the plant designs proposed by the two bidders, they were sufficiently alike to permit use of the same site arrangement. This arrangement is such as to require a minimum of excavation, to provide a satisfactory circulating water channel with deep water at the intake and a remote discharge on the opposite side of the island, to provide simplified fuel handling, and to provide adequate space for substation, miscellaneous services, and one additional nuclear unit.

(3) Plant description: The equipment and plant arrangements which were proposed by the two manufacturers were described in some detail in their proposals. Additional equipment and further comment on the plant arrangement were included in the report of the power engineering consultant.

The nuclear steam generating plant as proposed by both manufacturers is of the heterogeneous, pressurized light water type, utilizing uranium oxide fuel elements of low enrichment. In their principal features, the proposed reactors and primary systems are similar to others of the same type for which descriptions have been published.

Moderate pressure saturated steam is generated in a secondary system to serve a nominal 60 megawatt turbine generator unit. The turbine plant in general is based on conventional design practice, except that special provisions must be made for the problems of handling low pressure saturated steam. Electrical equipment would be conventional in most respects.

The two proposals required different designs of containment vessels and fuel handling, and this led to preparation of separate plant arrangement drawings, prepared in sufficient detail to obtain quantities for cost estimating purposes.

The waste disposal system was the most costly nuclear plant component not provided for by either bidder. Because the ultimate disposal of waste has not been established, it was difficult to appraise the cost of this system. The layout as conceived by our consultants provides for underground storage of the long-lived waste products and the release of low activity materials at a rate consistent with prevailing United States regulations.

The major differences between the designs of the bidders are shown in the following tabulation:

	Proposal A	Proposal B
Reactor power (megawatts)	250	236
Reactor power (million British thermal units)	853	805
Core life (full power hours)	15,840	10,000
Initial core enrichment (percent U-235)	2.2	2.54
Core loading (Kg UO_2)	23,830	6,930
Primary coolant system pressure (pounds per square inch, absolute)	1,620	2,000
Primary coolant inlet temperature (°F.)	480	491
Primary coolant outlet temperature (°F.)	510	520
Primary coolant flow (gallons per minute)	60,000	60,000
Steam pressure at boiler outlet (pounds per square inch, gage)	405	505
Steam temperature at boiler outlet (°F.)	449.4 (sat.)	471.1 (sat.)
Number of boilers	2	3
Number of primary coolant pumps	4	3

(4) Plant installation costs: Plant costs were developed in two stages. In the first stage, comparison was made between the proposals from the 2 nuclear equipment manufacturers, and since the proposals not only differed in basic design but also in equipment coverage, estimates were made of additional costs necessary to bring the 2 proposals to a comparable basis. In the second stage, these initial estimates were corrected for conditions that will apply when the plant is constructed, giving particular attention to labor costs, price escalations, ocean freight and handling, and local charges.

Proposal A provided only for reactor plant equipment necessary for the generation of steam, including reactor, pressurizer, steam generators, primary pumps, piping, and directly related equipment. No turbine generator or electric plant equipment is included.

Proposal B provided essentially all the items furnished under proposal A and in addition included a turbine generator unit, feedwater heaters, boiler feed pumps, power piping, condenser, and switchgear.

The costs of major equipment included in proposal B but not in proposal A, and the costs of equipment not included in either proposal were estimated by determining the requirements through heat balance calculations or other design criteria; and on the basis of these, brief specifications were prepared and prices obtained from manufacturers.

Initial estimates were made in terms of cost levels applying between May and December of 1956. They include a blanket 10 percent contingency, but this factor is not intended as coverage for probable increased costs of labor and material. Furthermore, the 10-percent allowance should not be considered as applicable uniformly to all items of equipment. For example, 5 percent may be sufficient for conventional items, but in other areas the uncertainties as to design and construction requirements call for much larger allowances.

Engineering and supervision is provided for by a 5-percent estimate based on the total of construction cost and allowance for contingencies.

These initial cost estimates as of 1956 are shown for proposals A and B in tables II and III, the first column of which indicates the dollar cost of equipment and material delivered to a United States port. Column 4 shows the estimated cost of local materials and labor payable in Philippine pesos but expressed in terms of United States dollars. Field labor costs in the Philippines are approximately 50 percent of corresponding costs in the United States and this difference is recognized in compiling the estimates.

The estimates up to this point (columns 1 and 4 of tables II and III) must be corrected for conditions that will apply at the time and place the plant is constructed. The primary variables to be considered relate to ocean freight and handling (col. 2), local charges (col. 3), and labor and material escalations applicable to columns 1 and 4.

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TABLE II.—*Initial preliminary cost estimate, 60-megawatt nuclear powerplant, proposal A basis*

Description	Material cost, United States (1)	Total dollar cost including freight, etc. (7.5 percent) (2)	Local charges (20 percent) (3)	Local materials and labor (4)	Grand total (5)
Land accounts	$25,000	$26,875	$5,000	$119,000	$250,875
Structures	411,000	441,825	82,200	331,000	855,025
Reactor plant shielding	60,000	64,500	12,000	134,000	210,500
Containment vessel	450,000	483,750	90,000	450,000	1,023,750
Water supply structures	55,000	59,125	11,000	230,000	300,125
Miscellaneous permanent structures	100,000	107,500	20,000	241,000	368,500
Reactor plant equipment	9,235,600	9,928,270	1,847,120	480,000	12,255,390
Standard plant equipment:					
(*a*) Mechanical	4,185,000	4,498,875	837,000	450,000	5,785,875
(*b*) Electrical	616,600	662,845	123,320	343,400	1,129,565
(*c*) General	648,000	696,600	129,600	106,000	932,200
(*d*) Substation	640,000	688,000	128,000	260,000	1,076,000
Subtotal	16,426,200	17,658,165	3,285,240	3,244,400	24,187,805
Contingencies, 10 percent	1,642,620	1,642,620		324,440	1,967,060
Engineering and supervision, 5 percent	1,307,740	1,307,740			1,307,740
Interest during construction, 6 percent			1,569,290		1,569,290
Total, based on 1956 prices	19,376,560	20,608,525	4,854,530	3,568,840	29,031,895
Total, including escalation					36,554,660

NOTES

(*a*) Initial core loading not included.
(*b*) Local charges include duty, import taxes, local handling, bank charges, compensating tax, and stores expense.
(*c*) Based on installation on property currently owned by Manila Electric Co at Talim Island, Luzon, Philippine Islands.

TABLE III.—*Initial preliminary cost estimate 60-megawatt nuclear powerplant, proposal B basis*

Description	Material cost, United States (1)	Total dollar cost including freight, etc. (7.5 percent) (2)	Local charges (20 percent) (3)	Local materials and labor (4)	Grand total (5)
Land accounts	$25,000	$26,875	$5,000	$235,400	$267,275
Structures	411,000	441,825	82,200	331,000	855,025
Reactor plant shielding	130,000	139,750	26,000	314,000	479,750
Containment vessel	650,000	698,750	130,000	450,000	1,278,750
Water supply structures	55,000	59,125	11,000	230,000	300,125
Miscellaneous permanent structures	100,000	107,500	20,000	241,000	368,500
Reactor plant equipment	10,519,000	11,307,925	2,103,800	480,000	13,891,725
Standard plant equipment:					
(*a*) Mechanical (*b*) Electrical (*c*) General (*d*) Substation	6,791,660	7,301,035	1,358,332	1,159,400	9,818,767
Subtotal	18,681,660	20,082,785	3,736,332	3,440,800	27,259,917
Contingencies, 10 percent	1,868,166	1,868,166		344,080	2,212,246
Engineering and supervision, 5 percent	1,473,608	1,473,608			1,473,608
Interest during construction, 6 percent			1,768,330		1,768,330
Total, based on 1956 prices	22,023,434	23,424,559	5,504,662	3,784,880	32,714,101
Total, including escalation					41,224,190

NOTES

(*a*) Initial core loading not included.
(*b*) Local charges include duty, import taxes, local handling, bank charges, compensating tax, and stores expense.
(*c*) Based on installation on property currently owned by Manila Electric Co. at Talim Island, Luzon, Philippine Islands.

Recent experience in construction of conventional units by Manila Electric Co. indicates that the costs for ocean freight and handling approximate 7½ percent of the equipment and material costs supplied from the United States, and such allowance is included in tables II and III. On the assumption that ad valorem rates would not necessarily apply, and in consideration of the higher cost per unit of weight or volume applicable to the nuclear plant, it was considered reasonable to reduce the cost of ocean freight and handling to 5 percent, and such rate is used in the summary tabulation of costs (table IV) applicable to 1961 completion of the nuclear plants.

Recent experience modified by scheduled changes in various taxes, indicates that an overall rate of 20 percent applied to United States equipment and materials is reasonable coverage for duties, import taxes, local handling, bank charges, compensating tax, stores expense, etc. The 20 percent rate for local charges may be on the low side, particularly if additional taxes and duties now unforeseen should develop in the next few years.

If the nuclear plant were to have been started in 1957, completion might have been expected in 1961. On the other hand, basic costs are related to 1956 price levels. It seemed reasonable, therefore, to allow for escalation corresponding to an average interim of at least 3 years. On the basis that recent experience indicates approximately 10 percent per year increase in the cost of equipment and materials, an allowance of 30 percent over 1956 costs is consistent with the earliest possible construction time. For the total of local materials and labor, in which labor represents approximately 45 percent of the cost, a lower percentage would seem appropriate. Based on the current United States experience, which indicates approximately 5 percent per year increase in labor rates, an escalation of 15 percent has been allowed. If the application of this rate in the Philippines provides too low an escalation, it is at least consistent with the intent to estimate minimum costs.

Table IV, which reflects these several adjustments related to both the time and place of construction, also includes the cost of the conventional oil-fired unit for comparison with the nuclear proposals. For convenience in presentation, however, the conventional oil-fired plant is discussed in a separate section.

TABLE IV.—*Summary tabulation of costs, 60-megawatt units*

	Nuclear plant		Conventional oil-fired unit
	Proposal A	Proposal B	
1. Subtotal, United States material	$21,354,060	$24,286,160	$8,709,740
2. Contingencies	[1] 2,135,400	[1] 2,428,610	[2] 435,490
3. Ocean freight and handling	[3] 1,067,700	[3] 1,214,300	[3] 653,230
4. Miscellaneous local charges, 20 percent	4,270,810	4,857,230	1,741,950
5. Local materials and labor	3,731,060	3,956,920	1,463,850
6. Contingencies	[1] 373,100	[1] 395,690	[2] 73,200
7. Subtotal	32,932,130	37,138,910	13,077,560
8. Engineering and supervision, 5 percent	1,646,600	1,856,950	653,880
9. Interest during construction, 6 percent	1,975,930	2,228,330	784,650
10. Total dollar expenditure (lines 1, 2, 3, and 8)	26,203,760	29,786,020	10,452,340
11. Total local expenditure (lines 4, 5, 6, and 9)	10,350,900	11,438,170	4,063,750
12. Grand total	36,554,660	41,224,190	14,516,090
13. Dollars per kilowatt-hour installed (line 12/60,000)	609	687	242

[1] 10 percent.
[2] 5 percent.
[3] 7.5 percent.

In developing the above data, our consultants have made use of minimum costs for those items where considerable uncertainty might be expected to exist. Because of the insufficient background of completed nuclear plants and the rapid development of technology, it could be expected that there are areas of uncertainty wherein a broad range of cost might apply. In order to avoid statements of a range of costs, it was agreed that minimum costs should be used; and consequently the total cost of a nuclear plant may be 10 to 20 percent over the figures shown above. It is not expected, however, that final cost would exceed estimates

to the extent that has been noted in some of the earlier planned nuclear projects, for advantage has been taken of the use of a developed reactor type and of the experience derived from these other programs.

(5) Plant production costs: Although the estimates of nuclear fuel costs are discussed elsewhere in this report, it is appropriate in this section to consider certain basic information regarding the operation of the generating plant and the Manila Electric Co.'s system requirements. Because of the characteristics of the Manila load and of the present and expected availability of hydroelectric energy, it would be impractical to operate the nuclear powerplant at an average load of more than 50 megawatts. If the plant were used 8,000 hours per year, the net annual generation would be 400 million kilowatt-hours representing an average use factor of 76 percent. Frequently the manufacturers of nuclear equipment consider use factor as equivalent to the percentage of time that a unit is operated at full load. On this basis, 400 million kilowatt-hours would represent full load operation for only 6,667 hours. Because plant heat rates are different at full and partial loads, it is necessary to distinguish between these two situations if a reasonable estimate of fuel cost is to be made.

Net plant heat rates at various loads depend upon calculated heat balances and requirements for auxiliary power. Heat balances at several load points were obtained from the manufacturer who supplied the cost and other information relative to a turbine to be used with proposal A; only a full load heat balance was available with the information submitted as part of proposal B. Our consultants estimated the auxiliary power requirements in consideratble detail; and these were found to be 2 to 3 times as high as those required in a conventional plant. The combined effect of heat rate and auxiliary power, at full and partial loads, is illustrated in the following tabulation:

Net station output	60 megawatts	50 megawatts	30 megawatts
Turbine heat rate, B. t. u. per kilowatt-hour	12,461	12,600	13,400
Auxiliary power, percent	9.6	12.5	20.5
Net station heat rate, B. t. u. per kilowatt-hour	13,784	14,400	16,855

Based on the assumption of 8,000 hours' use at an average net output of 50 megawatts during the first few years of service, the utilization of the nuclear core heat and the estimated life of the core is determined in the following table:

	Proposal A	Proposal B
Reactor power (megawatts)	250	236
Core life (full-power hours)	15,840	10,000
Total heat produced (million British thermal units)	13,515,480	8,054,600
Station heat rate (British thermal units per kilowatt-hour at 50 megawatt average output)	14,400	13,680
Million kilowatt-hour produced per core	938.6	588.6
Annual net generation (million kilowatt-hour)	400	400
Operating life of core-years	2.346	1.472

In addition to fuel costs, which are based in part on the above table, it is necessary to estimate other operating and maintenance requirements.

It was estimated that the nuclear plant would require 56 employees at a total annual cost of approximately $192,000. Because there is no experience with maintenance of such nuclear plants, it is almost impossible to estimate the costs other than labor, and any figure that may be used would be subject to considerable error. With full recognition of this fact, it is assumed that the total operation and maintenance costs, other than fuel, are approximately double the labor component, making a total estimate of $400,000 a year, or 1 mill per kilowatt-hour.

(6) Conventional oil-fired unit costs: It was deemed important for comparative purposes to develop the costs of a conventional oil-fired generating unit of the same electrical capacity and for the same time of installation as the nuclear plant. Our consultants had designed and supervised construction of the existing four 25-megawatt units at Rockwell station and are currently en-

gaged in work on addition of a fifth 25-megawatt unit. With this background, they had recently prepared an estimate for a 60-megawatt plant for installation in Manila somewhat earlier than 1961.

The conventional unit, appropriately considered as an alternative to the nuclear-power addition, would consist of an 1,800 pounds per square inch gage, 1,000° F./1,000° F., oil-fired steam generator, 3,600 revolutions per minute tandem compound turbine generator unit, and a normal complement of auxiliary boiler and turbine plant equipment. Although this turbine has a maximum rated capacity of 60 megawatts, it is expected that it would have a capability of approximately 66 megawatts under actual operating conditions.

Present planning indicates that one 60-megawatt steam unit may be installed at Rockwell station in 1960, and a second such unit will be needed in 1961. For comparable times of installation, the nuclear unit should be compared with the second 60-megawatt conventional unit. Because new intake structures and equipment and additional storage facilities at Rockwell are required with the first 60-megawatt unit, the cost of the second unit would be somewhat lower than the first one on the basis of current price levels. It appears that the Rockwell site is suitable for installation of 200 to 300 megawatts of additional conventional generating capacity, although additional expenditures for circulating-water facilities will be required as units are added. On the other hand, for comparative purposes, data have also been developed for a conventional unit installed in a completely new station which would cost more than additional units installed at Rockwell.

The cost estimate for a 60-megawatt unit at Rockwell is shown in table V. This is in the same form as tables II and III, which detailed the costs for the nuclear proposals A and B. The United States material costs, based on 1956 levels, are shown in column 1, and local materials and labor in column 4; in other columns, adjustments are made as follows: In column 2, an allowance of 7½ percent of the United States material costs for ocean freight and handling, and in column 3 an allowance of 20 percent for local charges. The only adjustment that differs from that made in the nuclear-plant estimates is the allowance for contingencies, which is here reduced to 5 percent.

TABLE V.—*Initial preliminary cost estimate, 60-megawatt oil-fired reheat unit, Rockwell station*

Description	Material cost, United States (1)	Total dollar cost including freight, etc. (7.5 percent) (2)	Local charges (20 percent) (3)	Local materials and labor (4)	Grand total (5)
Powerplant building	$695,000	$747,120	$139,000	$640,000	$1,526,120
Boiler-plant equipment	2,264,600	2,434,450	452,920	310,000	3,197,370
Turbine-plant equipment	2,702,200	2,904,870	540,440	195,000	3,640,310
Station electrical	670,000	720,250	134,000	65,000	919,250
General plant equipment	28,000	30,100	5,600	15,000	50,700
Substation equipment	340,000	365,500	68,000	48,000	481,500
Subtotal	6,699,800	7,202,290	1,339,960	1,273,000	9,815,250
Contingencies, 5 percent	334,990	334,990		63,650	398,640
Engineering and supervision, 5 percent	510,700	510,700			510,700
Interest during construction, 6 percent			612,830		612,830
Total, based on 1956 prices	7,545,490	8,047,980	1,952,790	1,336,650	11,337,420
Total, including escalation					14,516,090

NOTES

(*a*) Local charges include duty, import taxes, local handling, bank charges, compensating tax, and stores expense.
(*b*) Based on installation as No. 7 unit at Rockwell station.

A total 1961 installed cost of $14.5 million, or $242 per kilowatt, is the result of this analysis. If the 60-megawatt unit were assumed to be installed as the first unit in a new plant, the cost would increase approximately $1.5 million, resulting in a unit cost of $267 per kilowatt.

For direct comparison with the nuclear plant, it is here assumed that the conventional unit will produce the same annual net generation. At an average load of 50 megawatts, the net station heat rate is expected to be 9,731 British thermal units per kilowatt-hour. At the current fuel price of approximately 67 cents per million British thermal units, this results in a fuel cost of 6.52 mills per kilowatt-hour. If it is assumed that oil costs will increase at the rate of 2 percent per year, the fuel cost in 1961 will be approximately 7.05 mills per kilowatt-hour.

Based on extrapolation of present experience in the Manila electric system, it is estimated that operation and maintenance costs for this unit would total approximately $160,000 a year, or 0.4 mill per kilowatt-hour.

(7) Addition of a superheater to the nuclear plant: The use of saturated rather than superheated steam in the turbine represents a return to practices which were found unsatisfactory many years ago. The use of saturated steam, however, is necessary because water-cooled reactors are limited to low temperature heat production and superheat can be achieved only by the addition of heat from fossil-fuel-fired sources. The use of saturated steam has major disadvantages both with respect to (*a*) the size and initial cost of the turbine, condenser, and related equipment, and (*b*) the effective utilization of the available heat energy.

If an oil-fired superheater is added to the reactor plant contemplated under proposal A, with the steam flow held constant and the steam temperature increased from about 450° to 750° F., the net electrical output will increase from 60 megawatts to approximately 82.5 megawatts. It was estimated that the additional and changed equipment would add a total of $2 million to the basic cost of a nuclear unit. Additional capacity is, therefore, obtained at a cost of approximately $90 per kilowatt, and the total installation cost is reduced to approximately $460 per kilowatt.

Since the increased size of this plant is predicated on utilizing the full power output of the reactor plant, the same core life and annual nuclear-fuel costs would apply. Overall, however, the heat rate is reduced to about 12,500 British thermal units per kilowatt-hour. This reduction indicates that the heat added by the superheater can be efficiently used at a rate somewhere near 9,000 British thermal units per kilowatt-hour. This incremental rate is better than that available from the conventional 60-megawatt unit but is fairly well in line with the incremental rate obtainable if the size of the conventional unit were similarly increased from 60 megawatts to approximately 82.5 megawatts.

Overall, it is expected that there would be little difference in unit production costs in the 60-megawatt nuclear plant without superheater and in the 82.5-megawatt superheated nuclear plant, based on estimates of 1961 fuel prices. On the other hand, when and if nuclear-fuel prices are further reduced, and if oil prices continue to rise, production expense from the superheated plant would actually be higher than that from the nuclear plant supplying saturated steam.

Advantage, if any, in the superheater with this particular situation appears to be limited to a reduction in the estimated cost of construction to approximately $460 per kilowatt. However, if consideration is given to the superheated nuclear plant, then the alternative conventional unit used for purposes of comparison must also be increased in size. Such an increase involves a relatively low cost for the additional capacity, i. e., a conventional unit of approximately 82.5-megawatt capability would cost approximately $18 million, or $218 per kilowatt, in an existing station, or approximately $19.6 million, or $237 per kilowatt, in a new station. Consequently, the total dollar difference between the nuclear and conventional plant costs, which must be justified by nuclear-fuel savings, remains in the neighborhood of $20 million.

The addition of the superheater to a 60-megawatt nuclear plant requires the use of a larger unit than is presently best adapted to the Manila system. If, as an alternative, the electrical capacity of the superheated plant were limited to 60 megawatts, it appears that the cost of this installaion would exceed the estimated cost of a straight nuclear plant of the same capacity.

D. Fixed charges: Normally, in an economic evaluation of two or more alternate plans of development, a comparison of the relative fixed charges or costs applicable to the various investment programs would be made. Here, and as usually is the case in the building of new electric power supply facilities, the capital investment required is relatively large per unit of capacity or output, or per dollar of revenue to be realized. In such cases, the fixed costs of depreciation, taxes, insurance, and return on investment are a large proportion (50 percent or more) of total annual costs or costs per unit of output.

We have concluded that it is unnecessary to make a full fixed-cost evaluation of the nuclear powerplant proposals now before us. There are several major reasons for this conclusion.

(1) The capital costs of both nuclear powerplant proposals so far exceed those of a conventional plant of like capacity as to make them patently infeasible, even when judged by standards appropriate for a business-investment decision in a research and development project. The likelihood, moreover, of offsetting substantially this margin of investment over the next several core lives seems very remote. Thus, even on the basis of assumptions favorable to the nuclear plant, the potential savings (both immediately and over the next decade) from the use of nuclear fuel as against conventional fuel are not sufficient to support more than approximately one-half of the excess costs of the nuclear reactor plant.

(2) A much larger proportion of nuclear powerplant investment consists of short-lived items of equipment than in the conventional plant. Moreover, the service lives of these equipment items are still very much a matter of conjecture, without any firm foundation from experience. This will significantly enlarge the depreciation component of nuclear plant fixed costs.

(3) In the absence of special tax advantages, the capital cost components of the fixed charges for foreign investments are necessarily higher than those applicable to domestic investment. This is particularly the case for investment in those foreign countries such as the Philippines where exchange controls and limitations on permissible remission of return on investment are in effect.

If, despite the factors referred to in paragraphs (2) and (3), one uses for the Manila project a fixed charge rate such as is employed for *conventional, domestic* utility investments, the high degree of economic infeasibility of the Manila project, *at the present time*, is clearly demonstrated. Depending upon the area in which located (with associated local tax and related components) and the purposes for which employed, domestic utility companies generally use fixed charge rates of 12–15 percent in connection with their economic studies of alternate plant development programs. For its power value calculations, the Bureau of Power of the Federal Power Commission employs a fixed charge rate of 11.7 percent.[1] (The lower FPC rate is largely a consequence of the use of sinking fund depreciation and a low overall rate of return on investment; namely, 5½ percent. Moreover, this FPC fixed charge rate was geared to the lower bond interest rates obtaining several years ago and presumably would be significantly increased today to reflect the higher current costs of debt capital.[2])

If, despite the realization that the FPC fixed charge rate is out of date and that it gives no recognition to the important factors referred to in paragraphs (2) and (3) above, we were to use the FPC's 11.7 percent rate, the disparity in investment of approximately $333 per kilowatt between the nuclear plant ($600 per kilowatt) and the conventional plant in a *new* location (at $267 per kilowatt) means an economic penalty for the nuclear plant *on the most favorable conceivable basis* of $39 per kilowatt per year or 5.8 mills per kilowatt-hour. As has been demonstrated above, there are no reasonably foreseeable fuel savings available to offset more than approximately one-half of that penalty.

A fixed charge rate applicable to a conventional fossil fuel domestic plant was employed solely for purposes of analysis in order to determine whether, on this most favorable assumption, the nuclear project was within the target area of economic possibility. The basic nature of the understatement of fixed costs which this involves is illustrated by the fact that the rate uses sinking fund depreciation applied to an average service life of 30 years. Substantial parts of the investment in the proposed nuclear plants would have shorter lives than 30 years, and would undoubtedly reduce that average. Some estimates of service lives and depreciation rates of reactor facilities that have thus far been put forward anticipate shorter service lives and higher depreciation rates by factors of two more, compared with conventional fuel plant equipment.

Even in the turbogenerator portion of the plant, the design characteristics of the turbine for the nuclear powerplant are of a technological vintage of a generation ago, except in special circumstances. This is clearly apparent when one compares the pressures and temperatures for the same size of turbine now being

[1] See memorandum of Federal Power Commission submitted at the 1953 hearings before the Joint Committee on Atomic Energy, 83d Cong., 1st sess., on Atomic Power Development and Private Enterprise (printed record, pp. 122–125).

[2] So far as the Manila project is concerned, the increase in bond interest rates would not be offset by the option of liberalized depreciation for tax purposes made available by the 1954 Internal Revenue Code, since liberalized depreciation would not affect the tax liabilities on taxable income arising from the Manila project.

engineered for Manila, but using conventional fuel. Bearing in mind that the nuclear steam-generation portion of the plant is in an early stage of technological development, it is not credible to believe that the proposed 60-megawatt turbines for the nuclear plant, designed for 375–480 pounds per square inch gage saturated steam and 450–475 degrees F., will have the same or greater life than the 60-megawatt turbine, designed for 1,800 pounds per square inch gage and 1,000 degrees F., reheat conventional fuel plant. The former turbines, considered for normal electric power production use, are already partly obsolete and hence should carry a shorter economic life and higher depreciation rate consistent with the probable economic life of the reactor.

The higher depreciation rates probably applicable to a nuclear plant today, compared with a conventional powerplant, do not have the same partly offsetting benefits taxwise in a foreign installation as they might in this country. In the United States, to the extent the Bureau of Internal Revenue would accord recognition thereto for tax purposes, higher depreciation rates on a nuclear plant would mean a reduction in the tax component of fixed charges, whereas this would not be true in the case of an installation owned by a Philippine corporation where the Federal and Philippine income taxes on the return on GPU's investment are based on interest and dividends received.

In comparing a foreign nuclear versus conventional powerplant development, as alternatives, the unit capital cost components of fixed charges would not necessarily differ materially (apart from differences in capital structure deemed feasible for the alternate development plans), whatever might be the differences attributable to depreciation rates and costs. In other words, interest or dividends paid by Manila Electric Co. would not be subject to different rates of taxation, depending on whether the bond or share proceeds were invested in nuclear or conventional plant physical assets. The tax component of fixed charges or costs *in total dollars*, however, as in the case of depreciation, would vary, as between the two types of plants, depending on the relative investments required and the interest or dividends payable.

From the foregoing comments, it is clear that even though the capital costs *per dollar of investment* in nuclear versus conventional fuel powerplants would not materially differ, other fixed costs, and even the total dollar fixed costs, would be substantially higher for the nuclear powerplant than for the conventional fuel plant of the same capability. These high differential costs arise from the nature of the plants, the stature of the technology, and the relative investments required. These are circumstances which, in addition to the substantially larger investment cost of a nuclear powerplant at the present time, make inappropriate the acceptance now of either of the manufacturers' proposals that were submitted. Furthermore, this admittedly partial fixed cost evaluation suggests the advisability of seeking ways and means not only of reducing the investment and capital costs of the nuclear powerplant, but also of finding out how far the nuclear facilities can be pushed reliably, under actual load conditions, and what the operating performance and costs of using these facilities really are.

SCOPE AND METHOD OF INVESTIGATION

Basic data were assembled and preliminary conclusions were reached by an evaluation task force. This task force was composed of (*a*) personnel of GPU and its subsidiary companies who had previously had specialized training or experience in nuclear work, (*b*) representatives of GAI, and (*c*) representatives of PWL. Messrs, Marks and Trowbridge, GPU legal advisers on nuclear matters were consulted frequently. Initial conferences were held in 1955 with four of the leading manufacturers of electric generating and steam producing equipment that were also known to be participating in nuclear equipment development. The central aim of these initial conferences was to determine whether they believed it was feasible and timely to seek firm price proposals for nuclear powerplant equipment in the same manner as for conventional fuel plant equipment. Upon receiving generally affirmative responses, specifications were prepared and were issued in January 1956. Proposals were sought by June 1956.

After issuing these specifications, the GPU group offered to confer with the manufacturers, and held at least four conferences to clarify any questions as to the scope, nature, and intent of the specifications.

As previously noted, proposals were submitted by two companies. One proposal was for a nuclear steam generator only, while the other was for an almost complete nuclear electric powerplant. A series of conferences were held with

the manufacturers to determine in detail what items of equipment were included in the proposals' basic price and to agree on the nature of and need for items of equipment excluded from the proposals.

Our consultants then proceeded to prepare preliminary engineering estimates of the cost of a complete plant and to estimate the nuclear fuel cost for initial and subsequent cores. For the nuclear powerplant this required that they (*a*) make a tentative plant layout on the site selected; (*b*) obtain cost estimates for the omitted items; (*c*) check the adequacy and reasonableness of the United States materials costs assigned or assignable to each major piece of equipment or functional part of the plant; (*d*) estimate the transportation costs for shipment to the plant site, and the handling costs associated therewith; (*e*) estimate the labor requirements and costs involved in building the plant and installing the equipment at the site; (*f*) estimate the general overheads, field overheads, allowances for omissions and contingencies, and engineering expenses both in the design office and in the field; (*g*) compile all these data in a preliminary cost estimate; and (*h*) appraise the probable reasonableness and adequacy of the detailed and overall estimates. As an aid in this appraisal and as a basis of comparison, they also estimated the cost of a conventional fuel plant of the same capacity. In addition, special consideration was given to, and estimates made of the personnel needed to operate and maintain the plant and the costs thereof. Parallel and independent studies were made of the two proposals. From time to time during the preparation of these cost estimates, conferences were held with the manufacturers to clarify items of information and certain cost estimates.

Nuclear fuel costs were determined for the first and subsequent cores for both proposals by identifying and studying each of the steps involved in the overall fuel supply and processing cycle. Those steps, included in the manufacturers' proposals, were identified, and the remaining steps analyzed so that total cost to GPU could be determined. Adequate account had to be taken of the embryonic state of the fuel-manufacturing art and of the fact that nuclear fuels are owned by the Federal Government and subject to several regulations regarding their handling, disposition, and the charges and credits involved in their use. Since fuel cycle costs are particularly sensitive to core life and to spent-fuel composition, as well as to fabricating and processing costs, these factors were studied, in as much detail as practical, and a judgment formed as to their probable accuracy. In carrying out this work, our consultants held several discussions with AEC personnel in Washington and in some of the national laboratories. It was also necessary for them to visit and discuss fuel-supply matters with the two reactor manufacturers involved on the Manila project, as well as others, including fuel processors, fabricators, and handlers, concerning their capabilities, processes, costs, scrap rates, and other matters. They also studied the problems and costs involved in overland and overseas shipping before preliminary shipping costs could be determined. This necessitated discussions with the Maritime Administration, shippers, and others.

After preparation of the preliminary evaluation figures, further conferences were held, first, to explain the steps in the evaluation, the sources of the estimates, and the basis thereof; and second, to receive any criticisms and suggestions for revision which the manufacturers cared to offer, after a period for examination and review of the figures. This type of investigation follows the pattern of preliminary engineering work and cost estimating that is normally done in making conventional fuel plant additions.

This investigation involved an unusually high degree of willing cooperation on the part of the equipment manufacturers, especially with those two that submitted proposals in accordance with specifications issued by GPU in January 1956. All told there were at least 18 conferences with manufacturers' representatives, of which number 12 were with the 2 submitting proposals. In some of these conferences a considerable proportion of the GPU system nuclear power group participated; in some only members of the GPU task force, or representatives of GAI and PWL participated. All parties recognized the need and value of these meetings because of the pioneering nature of such activities related to the planning and designing of a nuclear powerplant.

This investigation was designed to give, and we believe yielded, reasonably reliable cost figures, both for the plant and for the nuclear fuel costs, for a decision whether to go ahead now with either of the manufacturers' proposals for a nuclear powerplant on the Manila Electric Co. system.

APPENDIX B. SUMMARY TECHNICAL SPECIFICATIONS FOR A GPU UTILITY HOOK-ON REACTOR PROGRAM FOR SAXTON STATION

SCOPE

This specification is intended to cover the purchase, delivery, and erection of a nuclear-reactor steam-generator plant for the Saxton station of the GPU system. It is to supply steam to the existing steam headers for use in part or all of turbine-electric equipment listed in the attached table. The exact size of the reactor plant will be determined by the responses obtained from equipment manufacturers. From preliminary studies it is anticipated that the most likely size range will lie between 100 million and 250 million B. t. u. per hour in steam. The selection will be governed by the objective of the program—to produce a maximum of knowledge and experience with a minimum of investment commitments. A reactor is required which can be operated under actual load conditions to determine (*a*) the ultimate thermal capability and effective fuel use of the reactor, (*b*) its performance and reliability under variable load-carrying conditions, and (*c*) the minimum reactor investment required, without interference with the operability of the existing conventional fuel boilers and turbogenerators.

GENERAL REQUIREMENTS

The reactor plant is to be of (*a*) the pressurized water or (*b*) the boiling-water type and to meet the following general requirements:

(1) Reactor plant and associated equipment to be based on present technology standards as far as possible so that construction may proceed expeditiously.

(2) Reactor plant to be in operation by April 1960.

(3) Existing facilities at the Saxton station, such as the turbine-generators, condensers, circulatory system, feed heating and pumping system, electrical equipment, and general plant to be utilized to the fullest extent.

(4) Existing steam generating plant to be left undisturbed so that it can provide steam as needed for continued commercial operation of the Saxton station.

(5) Minimum essential reactor plant and accessory facilities are to be provided at the outset but with the understanding that additional apparatus may be added later as conditions dictate and experience warrants. Those facilities to be kept to a minimum include fuel handling and inspection, laboratory, waste handling, reprocessing, and instrumental controls.

SPECIFIC REQUIREMENTS

(1) Either the pressurized or boiling water type of reactor using light water as moderator and coolant, with slightly enriched uranium as fuel may be used. The use of heavy water is not excluded.

(2) The nominal basis design capacity, as fixed by current design limitations, is to lie between 100 million and 250 million B. t. u. per hour delivered in steam.

(3) Steam is to be delivered at pressure and temperature suitable for use with the presently installed turbine room equipment. Supplementary superheating arrangements may be required for this purpose.

(4) In order to minimize investment, a single primary loop may be provided initially but design should be such that alterations and additions may be made at later dates fully to utilize any increased capacity which may be demonstrated.

(5) Reactor vessel to accommodate 4- or 5-foot diameter core, to be provided with full-opening closure, and to be so arranged that alternative cores may be installed with the minimum of external alterations.

(6) Reactor loop equipment, heat exchangers, pumps, pressurizers, valves, pipe fittings, instruments, and controls to be of standard conventional types wherever practical and the selection of materials to be guided by the ultimate objective of minimum investment cost.

PRIMARY FEATURES AND DATA, SAXTON STATION

Owner: Pennsylvania Electric Co., Johnstown, Pa.

Plant location: Approximately 1 mile from Saxton, Pa., 20 miles south of Altoona, Pa. Constructed 1923–26.

Population density: Relatively sparse; Saxton population approximately 1,300; nearest larger town: Everett, with population of 8,000 15 miles south of site.

Property area: Adequate to support complete facility; property occupies an area approximately 2,200 feet long by 1,400 feet wide.

Accessibility: 20 miles from Pennsylvania Turnpike; 15 miles from nearest railhead.

Plant capacity: Nominal capacity 50,000 kilowatts; maximum capability, 64,000 kilowatts.

Turbine generators:

No. 1 unit: 10,000 kilowatts nominal capacity (13,000 maximum capability), single casing, 1,800 revolutions per minute, nonextraction, condensing unit. Full load steam rate 12.4 pounds per kilowatt-hour.

No. 2 unit: Same as unit No. 1, except full load steam rate of 11.7 pounds per kilowatt-hour.

No. 3 unit: 30,000 kilowatts nominal capacity (38,000 maximum capability), single casing, 1,800 revolutions per minute, extraction, condensing unit with 3 stages of extraction for feedwater heating. Full load steam rate 11.0 pounds per kilowatt-hour.

House unit: 937 kilowatts, 3,600 revolutions per minute, back pressure unit (2 pounds per square inch gage) for station auxiliary supply or backup.

Steam conditions: At all turbines, 285 pounds per square inch gage pressure, 630° F. total temperature, total steam flow to turbines, approximately 750,000 pounds per hour.

Turbine plant auxiliaries: Complete condensing, feedwater, and other supporting systems are in active service.

Boiler plant: Eight existing stoker fired Sterling type boilers and supporting auxiliaries. (These would remain as a secondary source of steam.)

Electrical facilities: Complete station electrical facilities, substation and 2 separate 115 kilovolt transmission networks.

MIDDLE SOUTH UTILITIES, INC.,
New York, N. Y., October 21, 1958.

Mr. JAMES T. RAMEY,
Executive Director, Joint Committee on Atomic Energy,
Congress of the United States, Washington, D. C.

DEAR MR. RAMEY: This is in response to your letter of August 21, 1958, requesting our views on the Joint Committee print entitled "Proposed Expanded Civilian Nuclear Power Program."

The Edison Electric Institute's Committee on Atomic Power also received your letter of August 21 and is sending you what I believe to be a thorough and thoughtful reply to it. The Middle South system companies have reviewed the EEI committee's reply to your letter and feel that the comments therein reflect the views of the Middle South companies on these questions. For this reason, we wish to endorse the EEI committee's response rather than undertake to formulate separate answers to the questions posed in your letter.

There is, however, one point which we wish particularly to emphasize. In the EEI committee's reply the position is taken that industry should be encouraged to take the initiative in proposing reactor projects to the AEC, rather than to have AEC designate which reactor projects are to be undertaken. We strongly support this position. We believe that such freedom of action for industry stimulates going ahead with projects in an expeditious manner.

A case in point is the project of Southwest Atomic Energy Associates, in which the four operating companies of the Middle South system—Arkansas Power & Light Co., Louisiana Power & Light Co., Mississippi Power & Light Co. and New Orleans Public Service Inc., are participants. The reactor concept envisioned by the SAEA project was selected by SAEA—not by AEC. The participating companies in SAEA and North American Aviation, Inc., the contractor for the project, consider the reactor to have substantial promise for the future, and AEC has written to SAEA that " * * * The program * * * appears to offer technology of a worthwhile value which would be supplemental to work presently being conducted." We feel that this country's atomic power development program will benefit if latitude in selecting reactor projects continues to be encouraged.

We appreciate your invitation to express our views on these matters.

Respectfully yours,

H. F. SANDERS.

NEW ENGLAND ELECTRIC SYSTEM,
Boston, Mass., November 25, 1958.

Mr. JAMES T. RAMEY,
Executive Director,
Joint Committee on Atomic Energy, Congress of the United States,
Washington, D. C.

DEAR MR. RAMEY: You have recently urged me to comment on the Joint Committee print entitled "Proposed Expended Civilian Nuclear Reactor Program" which you forwarded to me under your letter of August 21.

As you know from our talk, I find myself in substantial agreement with the objectives of this program and with the analysis of the technical problems that must be met before nuclear power can be firmly established as competitive with power from conventional plants. The suggested program seems well worked out and is bold and imaginative.

I have not commented earlier because of the difficulty I find in stating my broad agreement with the proposed program, without at the same time pausing to comment in detail on some of the specific problems that must be met and solved in carrying it out.

I believe my principal comments on the program go chiefly to matters of method and administration. There I feel it is of basic importance to recognize throughout that we are pressing for maximum results in an experimental field. The basic recipe here, I believe, is to launch the program on a broad front, investigating many different approaches but being alert at all times to eliminate unpromising leads in order to concentrate on more promising approaches. This course seems to me essential on both the technical and administrative fronts. Thus, while I believe the carefully delineated domestic and foreign programs outlined at the conclusion of the report may well be the most promising approaches today, we must not foreclose the use of other approaches in the future if they should become more attractive. Whenever a reactor concept under development indicates that it is unattractive or not appropriately competitive it should be cut out. This is usually very hard to do. The decision is difficult and there is always pressure "to throw good money after bad."

I should add in this connection that I am enough of an optimist to expect that, as the program unfolds, new developments will be undertaken at an accelerated pace by private capital, and that the cost of the program to the Government will correspondingly decrease. For this reason it seems undesirable for the Commission to undertake the construction of full-scale power reactors until such time as any new concepts have been carried well along in the R. & D. stage and translated into prototype reactors suitable for installation at AEC sites where any incidental power output could be consumed in connection with the Commission's own operations. Should it then be necessary for the Commission itself to undertake the construction of a full-scale power plant in order to carry out the primary objectives of the program, such a step should be planned and carried out on a nondiscriminatory basis as between public and private power systems and in full cooperation with the particular utilities which would be called on to absorb and distribute the power output of the plant upon completion.

Yours very truly,

WILLIAM WEBSTER,
Executive Vice President.

NIAGARA MOHAWK POWER CORP.,
Buffalo, N. Y., October 30, 1958.

Mr. JAMES T. RAMEY,
Executive Director, Joint Committee on Atomic Energy,
Congress of the United States, Washington, D. C.

DEAR MR. RAMEY: I have read with interest the Joint Committee report, Proposed Expanded Civilian Nuclear Reactor Program, dated August 1958.

I feel that the memorandum prepared by the committee's staff after conferences with the AEC and panel of reactor and industrial experts is an outline of a broad and sensible program designed to meet the requirements of our country in the field of nuclear power development during the next decade.

My answers to questions 1 to 4, inclusive, in your letter of August 21, 1958, are, "Yes."

In connection with question 5, it is my opinion that the group making the study is as familiar as any group in the country with such estimated costs, and I cannot question them.

I feel that the organization and policies proposed on page 9 are adequate as viewed at the present time. As the studies are progressed and changes are found to be desirable, they can be made at that time.

Sincerely yours,

E. S. BUNDY, *Director.*

NORTHERN STATES POWER CO.,
Minneapolis, Minn., October 15, 1958.

MR. JAMES T. RAMEY,
Executive Director, Joint Committee on Atomic Energy,
Congress of the United States, Washington, D. C.

DEAR MR. RAMEY: In response to your letter of August 21, 1958, we have given careful consideration to our views and comments on the proposed expanded civilian nuclear reactor program, dated August 1958, prepared by the Joint Committee. This program is vitally important to the future of the electric power industry as it is to the interests of the United States. It is very broad in scope and tremendously complex. For these reasons it is difficult to state our comments concisely, but we have endeavored to do just that because we appreciate that you will have many such replies to review and consolidate.

It is our general comment that the program would tend to invade the area of administrative responsibility which should be left to the AEC, and in thus limiting the flexibility of authority of the Commission, it may seriously hamper the progress toward the objectives which all of us are seeking. It is also our general observation that, although the objectives of the Joint Committee as stated in the print are plausible and in many ways desirable, the critical factors are the application of the principles stated therein to specific situations, specific plants, and specific locations. It is in these applications that the future welfare of the electric power industry may be vitally concerned.

In the following numbered paragraphs we are replying concisely to the questions under corresponding numbers in your letter. Having stated the foregoing general comments, we will not repeat them as limitations under the specific items but obviously they do affect those comments throughout.

1. *Major objectives.*—The three major objectives, we believe, are desirable, and in general we agree with them. We have some questions about the desirability of setting down specific dates for attaining competitive nuclear power, but we feel that this question is one for the agency directing the program to determine.

2. *General technical objectives.*—The general technical objectives of the program appear to us to be adequate. Emphasis should be put upon the cost of fuel including processing, improved burnup, reprocessing, and waste disposal.

3. *Scope of the technological program.*—We are in accord with the proposal to step up the efforts on general fuel cycle development. In providing adequate test reactor facilities, we would encourage the plan of using existing and presently authorized reactors of the Government and of industry for test purposes to avoid constructing additional test reactors. We are in accord with the statement of objectives on page 7 of the Joint Committee print: "The goal of this design and construction program is primarily information and experience. Such information should make it possible to solve the major technical problems listed and thereby put the atomic-energy industry in this country in a position to design, build, and operate nuclear powerplants economically competitive with conventional sources of power; first, in other countries; ultimately, in this country." We are also in accord with the statement on page 7 which states, "It would be anticipated, in a number of cases, design studies or detailed design and estimates would show the particular proposal under review was unlikely to lead to lower costs and therefore should be abandoned. Such flexibility is essential to the program."

4. *List of reactors—Table I.*—Table I lists reactors of various types which should be undertaken in the near future, and it shows the dates of the start and finish of the project in each case. While we do not raise a question regarding any of the proposals in the table, we would call your attention to the fact

that the mere listing of such proposals in the program by your Joint Committee would lend such weight and authority to them that it would be difficult at a future time to deviate from the list or modify the program as later research would indicate. The whole field is new and new ideas and concepts are being developed throughout the industry. The program must adjust itself to this changing knowledge. The research and development program that would be most practical and would tend to the greatest progress in this field would be one which would permit of the widest discretion by those actually working in the field.

The staff of the AEC, we believe, should not be limited by a preconceived list of projects nor should those elements of industry which are now working in the field be so limited. Every effort should be made to encourage flexibility of scope as the various projects develop. We do not believe that the Joint Committee intends to limit the AEC in its approach to this problem, but we do reiterate that the mere existence of a list of proposed reactors for priority tends, itself, to limit them.

5. *Cost estimates.*—We have no comments concerning the cost estimates. They appear reasonable to us.

6. *Organization and administration.*—We agree that the AEC should continue to be responsible for the conduct of the base program of research and development through its national laboratories, industrial contractors, universities, and nonprofit institutions.

We believe that the program should give more recognition to the collaboration of the electric industry with the AEC in carrying out its administration. The tone of the language in the program indicates that a certain project contained in the prestated program or conceived by the AEC will be set up for invitation to industry to participate and in the absence of immediate response be constructed by the Government. We suggest that the program give full recognition to the possibility of a project being initiated by industry and accepted by the Commission, and we suggest that the tone be modified to give full discretion to AEC concerning the time to be allowed for a response to an invitation.

7. *Other types of assistance.*—Question No. 7 in your letter asks what types and amounts of assistance by the Government should be recommended for the domestic program and the foreign program. The answer to this question depends upon the urgency for a speedup of this whole program. Industry has indicated a keen interest in the development of economical nuclear power. Many utility companies and manufacturing companies have pledged sizable sums of money into building full-scale operating plants. This is as it should be. If a further speedup of the program is considered essential and industry is to be invited to explore certain untested concepts, then undoubtedly provision should be made for extending the amount of Government participation in the research and development phase of the project. We feel that this can be done without the Government's investing in the plant itself but merely by broadening the interpretation of research and development cost.

For example, in building a new reactor concept into a full-scale powerplant, practically every item going into the construction of the reactor is tailormade and carries with it unusual and perhaps unnecessary factors of safety. The second, third, and fourth rounds of construction of such a plant type might eliminate many of these factors and reduce the cost considerably. Therefore, in the first reactor to be built, a very broad interpretation of research and development is possible, whereas in the later construction of similar reactors a more limited definition would be practical.

It would be of assistance to the electric power industry in cooperating in the program to emphasize the flexibility indicated in the Joint Committee print, page 10, under "A. Privately Owned Plants," subparagraph No. 3, "* * * the commitment to construct may recognize certain possible unexpected developments in the project, such that the parties may mutually agree that insistence on plant construction would be unreasonable." Also, under No. 4, "The Commission would consider requests for research and development assistance under somewhat more flexible terms than previously." In research and development work, by its very nature, we are endeavoring to determine a course of action, and it is difficult to predetermine the amount of effort and expense accurately. The Commission should be allowed the maximum possible flexibility in the administration of these contracts. Such flexibility would make possible a maximum participation by industry.

In general it is the basic objective, as stated by the Joint Committee, to put the atomic-energy industry in this country in a position to design, build, and op-

erate nuclear powerplants economically. We submit that only through full participation by American industry in the construction and operation of large plants will the program achieve and demonstrate economic feasibility. It must be recognized that economic feasibility is not a prime requirement for Government appropriation and that, if the AEC has as a part of its administration program the construction by the Government of these large-scale demonstration plants, the question of economic feasibility will ultimately be lost.

The day will soon come when this whole problem of nuclear power will be left in the hands of industry to carry forward, and it is important that we do not now build obstacles to that free development which we know must come later.

We genuinely appreciate the opportunity you have afforded us to make these comments, and we urge your committee to give consideration to our suggestions.

Very truly yours,

ALLEN S. KING.

OHIO EDISON CO.,
Akron, Ohio, October 30, 1958.

Mr. JAMES T. RAMEY,
Executive Director, Joint Committee on Atomic Energy,
Congress of the United States, Washington, D. C.

DEAR MR. RAMEY: Reference is made to your letter of August 21, 1958, in which you requested my views and comments on the Joint Committee Print entitled "Proposed Expanded Civilian Nuclear Power Program."

With respect to the objectives of the program as stated on page 4 of the print, I am not sure what the phrase "nuclear power competitive in cost per kilowatt-hour" means. Fuel costs vary substantially in different parts of the United States. It is therefore quite possible that nuclear power could be competitive in some areas of the United States with power generated by conventional means long before it could be competitive in other areas of the United States.

Further, it seems to me that the objectives of an atomic power program of the United States Government should be designed and stated so that they come within the policy of Congress as set forth in section 1 of the Atomic Energy Act of 1954. I have particularly in mind that portion of the congressional policy set forth in section 1 b. of the act which states that "the development, use, and control of atomic energy shall be directed so as to * * * strengthen free competition in private enterprise." Accordingly, I do not believe that 1970 or any other predetermined year can be arbitrarily selected as the time by which competitive nuclear power can be achieved and demonstrated in this country.

This Nation presently has ample sources of economical fuels for energy and the supply of conventional fuels, of course, has a direct bearing on the time when nuclear power can compete with power generated by conventional methods. From this I believe it follows that the quantity of kilowatts developed by nuclear power is not the test of real progress and would not be indicative of our leadership in atomic energy development.

I believe that section 31 of the Atomic Energy Act of 1954 gives the Atomic Energy Commission ample power to insure the continued conduct of research and development in the field of electric power generation. Orderly research, development, and construction of a number of promising types and variations of experimental or small prototype reactors, to determine which type or types will ultimately prove more advantageous, in my opinion, will achieve optimum progress and hasten the day when atomic power will become truly economic. I am confident that if the expense of such research and development is equitably shared by the United States Government and companies engaged in private enterprise that sufficient experimental work will be done to achieve the objective of competitive nuclear power.

I do not believe that the Atomic Energy Commission should be given the exclusive right to select the types of reactors to be designed and constructed as indicated on page 9 of the print under paragraph (*c*) of the "basic policy" of the organization and administration of the program.

In conclusion I wish to again emphasize that no program should be engaged in to the detriment of our free-enterprise economic system.

I appreciate very much having had the opportunity to make these comments.

Very truly yours,

W. H. SAMMIS.

OKLAHOMA GAS & ELECTRIC CO.,
Oklahoma City, Okla., October 21, 1958.

MR. JAMES T. RAMEY,
Executive Director, Joint Committee on Atomic Energy,
Congress of the United States, Washington, D. C.

DEAR MR. RAMEY: Pursuant to your letter of August 21, we have read the Proposed Expanded Civilian Nuclear Power Program quite carefully. Inasmuch as I am not a technical man and since questions 2 through 5 appear to require at least a basic technological background, I do not feel immediately competent of answering these questions. There are below, however, responses to questions 1, 6, and 7.

1. Basically, the three objectives appear sound, although the realization of operating *competitive* plants in many parts of the United States, including Oklahoma, *by 1970* may be quite an ambitious program.

We cannot agree with some in the atomic field who believe that there is an impelling rush about the whole program. As a matter of fact it is possible that, regardless of the pressure put on a definite period for realization of objectives, its success could be improbable or even impossible. Our considered opinion regarding the whole program is that the plan should be more or less as follows:

Experimentation on various concepts should be prosecuted by individual private utilities or groups of individual private utilities with whatever assistance can be lent by the Federal Government. This is based on the premise that whatever portion of the investigatory expense is borne by the Federal Government will not have to be borne by the customers of the various private utilities, which is the only other source of such funds. We believe further that it is uneconomical to embark on construction of full-scale plants (except in isolated instances) during this investigatory period.

6. The policies stated seem reasonable for the immediate future; nevertheless, we feel that some written assurance included in the program should be given that the Federal Government has no intention of continuing to direct or control the electric utility industry when nuclear methods of steam production and electrical generation may at length become practical and economical. An attitude of continued Federal control could eventually result in socialization of the entire electric utility industry. This is not false or exaggerated thinking, because such governmental agencies as TVA and REA are even now expanding their operations and influence because *at their inception* the language used was not sufficiently specific to "fence in" the exact area which the Congress which approved the bill had in mind at the time. We, therefore, would strongly recommend more specific language on this particular point in the text of the Joint Committee print.

7. It seems to the private companies engaged in nuclear research that dependable and prompt supplying of fissionable source materials and other special nuclear materials and rare metals by the Atomic Energy Commission, which are not now generally available to private industry, would be Government's most valuable immediate contribution to private research. Such assistance has not been forthcoming in certain instances in recent months even though practical assurance of such assistance had been given at the inception of certain plans. For example, one case in point is the current hesitancy on the part of the Atomic Energy Commission to supply or guarantee to supply 50 kilograms of U–233 to Southwest Atomic Energy Associates by November 1959 so that their experiment with the fast breeder epithermal thorium reactor will not grind to a halt or have to be discontinued altogether.

It would also seem that the assumption that the electric utility business is to remain in private hands would anticipate that experimentation and research in specific projects should be vested predominantly with private utility groups and that such groups might be provided as much or little Federal subsidy as was felt should not be assessed against present electric customers. In this area the various State regulatory commissions might be of some assistance.

It was my privilege this summer to be one of a group which toured a substantial part of the electric power system of the Soviet Union. Our agenda was quite comprehensive and included visits to and discussions relating to their atomic reactors and their economic prospects under a socialistic, or rather, communistic regime.

We were informed by the managers that electric projects, when they are put into operation, required that the investment in the equipment be returned to the Government in not more than 25 years and that the investment in buildings

must be repaid in 50 years or less. With reference to the last requirement, it is their current thinking that 50 years is too long a period and they are restudying the situation with the idea of shortening this period.

It occurs to me that, if even under a communistic form of government it is considered sufficiently important from an economic standpoint that the cost of the plant be recouped through value of the power produced in a specified time, then it would be even more important as a requirement under our free-enterprise system. With this in mind, it would be my recommendation that no full-scale projects (except for limited experimental purposes in full-scale operation) be sanctioned by Government or constructed by private industry until their value can be recaptured in approximately the same time required for plants of conventional design and operation.

Very truly yours,

DONALD S. KENNEDY, *President.*

PACIFIC GAS & ELECTRIC CO.,
San Francisco, Calif., October 31, 1958.

Mr. JAMES T. RAMEY,
Executive Director,
Joint Committee on Atomic Energy,
Congress of the United States, Washington, D. C.

DEAR MR. RAMEY: This is the reply which you requested by November 1, 1958. It has not been possible for me to reply to your letter of August 21, 1958, until now because I was in Europe when the letter reached my office and I have only recently returned.

We have reviewed the Joint Committee print entitled "Proposed Expanded Civilian Nuclear Reactor Program," dated August 1958. We are in general agreement with the three major objectives of the program, provided they are carried out to the maximum practical extent by private enterprise, and we find the general technical objectives to be adequate.

The report divides the technological program into two categories: (1) basic research and development; and, (2) design and construction of various types and sizes of reactors, together with associated research and development.

It is our opinion that the AEC should concentrate its efforts on its basic research and development program, including construction and operation of the small experimental reactors required to demonstrate technical feasibility. We believe that this type of activity will make the greatest contribution toward the earliest fulfillment of the major objectives of the program, i. e. the development of nuclear power that is competitive in cost and fortifying the position of leadership of the United States in the peaceful applications of nuclear energy.

We do not believe that the second category of the technological program which proposes construction by government of successive generations of full-scale powerplants of types already in advanced state of development, such as pressurized boiling water reactors will accomplish its objectives in an efficient and economic manner. In our opinion this would be a duplication of effort and a waste of money. We believe that actual construction of reactors by AEC should be restricted to the types and sizes necessary to demonstrate technical feasibility.

Our own studies show that the boiling water reactor already stands on the threshold of generating competitive nuclear power. We are committed to constructing a 60 electric megawatt nuclear plant on Humboldt Bay by 1962. The unit cost of this plant is $325 per kilowatt and we expect that with the second core it will generate power at a cost competitive with power from a conventional plant of the same size burning fuel costing 48 cents per million British thermal units. We are continuing our studies of larger size plants with the object of further reducing capital and fuel costs and expect that this type of plant will be competitive throughout our service area by 1965. Furthermore, General Electric Co. has predicted that the unit capital cost of large size boiling water reactors will be in the range of $175 to $225 per kilowatt soon thereafter.

Achievement of competitive nuclear power will not occur uniformly throughout the United States. It is bound to occur first in areas where fuel costs are high and gradually spread to other areas as capital and fuel costs are reduced. In areas where low cost conventional fuel is available in ample quantities nuclear plants probably will not become competitive until their capital costs are no more than those of conventional plants.

In view of the foregoing and of our own experience in this field we believe that competitive nuclear power for high cost fuel areas is further along than many have realized, and that it is not realistic at this time to establish a definite program and date for the attainment of competitive power for the country as a whole.

Each of the answers to your seven questions, which follow, must therefore be modified by the foregoing general opinions.

1. We agree with the three major objectives of the program, subject to the foregoing comment.
2. The general technical objectives appear to be adequate.
3. The scope of the technological program is greater than necessary.
4. The proposed list of reactors in table I should be reduced to eliminate construction of large reactors and experimental reactors which would duplicate work underway.
5. The cost estimates appear to be reasonable for the described program but could be substantially reduced under our answer to question four.
6. The policies on organization and administration shown on page 9 include authority to construct large scale demonstration plants. We believe construction should be limited to plant sizes required to demonstrate technical feasibility.
7. Assistance for the domestic and foreign programs should generally be limited to basic research and development and the construction and operation of reactors only large enough to demonstrate technical feasibility.

Very truly yours,

N. R. SUTHERLAND.

PENNSYLVANIA ELECTRIC CO.,
Johnstown, Pa., October 28, 1958.

Mr. JAMES T. RAMEY,
Executive Director, Joint Committee on Atomic Energy,
Washington, D. C.

DEAR MR. RAMEY: This is in reply to your letter of August 21, 1958, asking my specific comments and views on the joint committee document Proposed Epanded Civilian Nuclear Reactor Program.

Before proceeding to answer the specific questions which you asked, I would like to make three general points:

My first point is simply that adequate provision be made for individual decisions and actions to be taken outside the framework of a specific Government program so that the proposed expanded civilian nuclear power program not be limited solely to the approaches presented in any such Government program.

The second is concerned with the entire approach of directing the Government's complex technical reactor program in detail by actions either of a semi-judicial body (the AEC itself) or of a legislative body (the Congress). In a fast-moving research and development field, maximum results can only be achieved by single-minded technical direction of the program. Such direction must have sufficient flexibility to permit the rapid capitalization on new developments either through earlier construction than had been anticipated or through abandonment of some intended course of action. Without it the very successful Borax or the apparently quite successful O. M. R. E. experiments could not have proceeded from the inception of an idea to actual operation in the extremely short periods of time they did. I doubt if either of those projects could proceed now on as quick a basis.

The difficulty with a detailed program specifically authorized by the Congress is simply one of flexibility. In the present framework perhaps no other course of action is satisfactory; however, I should like to record my feeling that the reactor research and development program of the Government could make more rapid progress if under a single responsible technical direction not too restricted in action. The Congress recognized this principle in the creation of the National Aeronautics and Space Authority under a single administrator.

The third general point I should like to make is that while I strongly believe that our present broad-base approach looking at a variety of reactor types should be continued, I feel that the water-cooled systems (both pressurized and boiling which I really regard as one type) should also be pushed harder than is contemplated in the proposed program, principally through increased emphasis on nuclear superheat.

Proceeding now to answer your specific questions, I would reply as follows:

1. Question. Do you agree with the three major objectives (p. 4) of the program? If not, what changes would you recommend?

Answer. Subject to changing the wording "demonstrate" in objectives (a) and (b) to "prove through actual full-scale operation" as discussed below and to adding "some areas in" before "in the United States" I agree fully with the three major objectives stated. This change also would apply to the first sentence on page 1, which would than read: "The objectives of this program are to prove, through actual full-scale operation, economically competitive nuclear power in some areas in the United States by 1970 and in 'high cost' free world nations by 1968."

The problem I have is that the words "to demonstrate" mean various things to various people and when associated with specific dates, considerable confusion arises. I do not believe that there is, in fact, any substantial difference in time between previous statements which have been made mentioning 1963 to 1965 for "demonstration" and your dates of 1968 and 1970 for "demonstration." The earlier dates were for initiation of construction projects and your dates, I believe, apply to operation of the same projects. I would suggest that this might be improved if the words "to demonstrate" were replaced by the words "to prove through actual full-scale operation." The restriction of the term "United States" to "some areas in the United States" is a refinement clearly indicated since some low-cost areas will certainly come later.

2. Question. Are the general technical objectives (p. 5) adequate? If not, what additions or deletions would you recommend?

Answer. I believe the statement of general technical objectives is excellent. I would suggest the addition of one new item:

"(k) Reduction in operating personnel requirements. This will require careful training, design and study of the use of automatice equipment and the reduction of unnecessary operations and supervisors to the maximum extent consistent with safety."

Also section (d) "Higher temperature steam." The type of prime mover involved in the program is referred to only in section (d), and here it is limited to a steam turbine. The objective of "higher temperature" should be broadened to cover any type of prime mover.

3. Question. Please comment on the adequacy of the scope of the technological program (p. 6).

Answer. Subject to the comment made in answering question 4 below, the scope of the technical statement appears quite adequate.

Concerning the third paragraph on page 8, I would like to emphasize that making nuclear power plant technical information in the military programs useful to the civilian programs is not wholly a security problem. The basic difficulty is that it takes time (and results in definite interference with the primary work objectives of the personnel involved) to convert information developed in the military programs to an unclassified form and then get it distributed to those who wish to use it. Furthermore, in many cases, the technical users are not satisfied with somebody else's predigestion of the data but wish to refer back to the raw data which (even if it is available from a classification standpoint) is usually properly denied on the basis of interference with the primary work objectives of the military program. This is a basic problem in our entire technology with the concepts of "need to know" and "compartmentalization." It is a difficult enough problem to get technical information around quickly to the actual users even in a completely unclassified field, without making it more difficult through security measures. I would suggest that a more positive statement than "consistent with security laws" might assist this stuation somewhat.

4. Question. In your opinion, is the proposed list of reactors in table I the best list for this program? If not, what changes would you recommend?

Answer. As mentioned in my general comments, I believe that the water-cooled system, pressurized and boiling, should move in the direction of nuclear superheat as quickly as possible. To this end I suggest that the 2 pressurized water reactors (listed as pressurized water, enriched uranium fuel, 200 electric megawatts; and boiling water, enriched uranium fuel, 200 electric megawatts) should both provide for some recognition of nuclear superheat.

Also I feel that, without detracting from the general philosophy of a broad and varied program, some projects should not be stated in such positive terms as they are in table I. In particular, I believe that the fifth item (75 to 150

electric megawatts aqueous homogenous solution reactor 1959–65) is premature. I also think that the last 5 reactors in the list (high temperature gas cooled, graphite or heavy water moderated, 200 electric megawatts; high temperature sodium cooled, graphite, or D^2O moderated, 200 electric megawatts; organic cooled reactor, 200 electric megawatts; sodium cooled fast or intermediate breeder, 200 electric megawatts; liquid metal fueled reactor, 50 electric megawatts) are all stated in far too definite terms and probably should be stated now only as "5 large-scale second generation central station plants," somewhat in the fashion of the entry sixth from the bottom on small reactors.

5. Question. Do you consider the cost estimates (p. 8) to be reasonable? If not, please point out the areas in which you disagree.

Answer. The cost estimates appear reasonable. I believe in all fairness that the costs and cost distribution for reactors now under construction and already implemented should be reflected in this paragraph for the sake of telling a complete story.

At this point I should also note that on page 13, last sentence of first paragraph of "Conclusion." Such a comparison is quite illogical and is no support for the committee's program. Better say, "The estimated cost is justified by the importance of the objectives."

6. Question. What is your opinion of the policies on organization and administration proposed on page 9? Will they adequately implement the positive leadership required for success of the program?

Answer. As covered in my first and second general points above, I feel that providing a framework for both an individual enterprise program and a governmental program with a single-minded technical direction given enough flexibility to operate in either area are the most important organizational and administrative steps. Until that is done I doubt that really successful positive leadership will be achieved.

On page 11, item B 2 (c) provides for construction, "(c) or at sites where power may be distributed to private companies consistent with section 44 of the Atomic Energy Act."

In view of the very considerable confusion around the precise intent of section 44 in this regard, I wonder if this requirement, coupled with the short time scale, might not prove very difficult for the Commission to handle. I have in mind the situation resulting at West Milton and the rather confused legal picture on this whole matter.

I do not clearly understand how paragraph C on page 9 (which, in essence, would provide for AEC construction of a selected reactor) is consistent with the contents of the paragraph on page 12 entitled, "Other Considerations Affecting Domestic and Foreign Atomic Power Programs." It would seem to me more reasonable that some alternate along the lines of the paragraph on page 12 should be included in the provisions of paragraph C on page 9.

The fact of the matter is that our present cooperative program is a most inflexible device, and I believe that knowledgeable executives in both the public and privately owned utilities would agree that some more flexible method of providing assistance could not help but accelerate the program. If even just a little more flexibility had been available, I am sure that several projects which have died aborning might by now have reached the construction stage.

7. Question. If it should later prove necessary, what other types and amounts of assistance would you recommend for the domestic program? For the foreign program?

Answer. There are a number of ideas which have come forth, including construction differential grants, fuel guaranties, and sliding-scale premium payments on nuclear kilowatt-hour generated, all of which are susceptible to equitable distributional between the public and private power groups. These schemes should be more thoroughly explored than has been done to date. I really think that it would be possible to get a representative group of utility people from both camps together to go more thoroughly into these possibilities. Perhaps you may be able to bring this out in the course of the seminars which you intend to hold this fall.

I trust my reply may be of use in connection with the Joint Committee's efforts to reach a mutually satisfactory long-range civilian program statement. I do not believe our situation in the civilian power field is at the present moment bad, indeed I think it is quite good, but it is indeed high time to lay plans for the future.

Sincerely yours,

LOUIS H. RODDIS, JR., *President.*

PHILADELPHIA ELECTRIC CO.,
Philadelphia, Pa., October 29, 1958.

Mr. JAMES T. RAMEY,
Executive Director, Joint Committee on Atomic Energy,
Congress of the United States, Washington, D. C.

DEAR MR. RAMEY: Thank you for your letter of August 21, attaching a copy of the Joint Committee print entitled "Proposed Expanded Civilian Nuclear Reactor Program" dated August 1958, and for the opportunity to comment on this program. Our company is a member of the Edison Electric Institute, and Mr. R. G. Rincliffe is a member of their committee on atomic power. This committee has forwarded comments to you in a letter signed by its chairman, Mr. Elmer L. Lindseth. We have no additional comments to offer at this time.

Very truly yours,

L. P. GATY,
Vice President, Research and Development.

SOUTHWESTERN ELECTRIC POWER CO.,
Shreveport, La., October 31, 1958.

Mr. JAMES T. RAMEY,
Executive Director, Joint Committee on Atomic Energy,
Washington, D. C.

DEAR MR. RAMEY: Thank you for your letter of August 21, 1958, requesting our comments on the Joint Committee print entitled "Proposed Expanded Civilian Nuclear Reactor Program." You have received a reply from the Edison Electric Institute Committee on Atomic Power, and we subscribe to their answers and comments. However, we have some further comments and suggestions, which are set forth below:

Question 1. Under heading "Program Objectives," we do not agree with the date, 1970, that you have set in section (a). The time in our service area is certainly more distant than 1970. We are presently negotiating a gas contract to cover all our fuel requirements (present plants and future plants) for the next 20 years, and while the price of gas is not guaranteed in the contract under negotiation, there is no reason to believe that the cost per kilowatt-hour at our gas-fired generating plants will be nearly as high over the next 20 years as the cost per kilowatt-hour from any commercial nuclear powerplant. We think you should change section (a) to read as follows:

"Achieve and demonstrate in the United States nuclear power at low cost with the hope that it will become competitive with other methods of production."

The following statements in the Joint Committee print show that program objectives will not be expedited by the schedule in table I, and that, although disclaimed, power per se will become the only objective. Under heading "General Technical Objectives," on page 6, in the second paragraph, appears the statement:

"Operating information which may lead to lower costs is just beginning to be developed and evaluated."

The value of this operating information is further stated about the middle of page 7, as follows:

"The goal of this design and construction program is primarily information and experience."

Now, it is difficult to find compatibility between such declarations and the following statement, which appears on page 15 in the appendix:

"Operating experience concerning high fuel burnup tests, maintenance, and high plant factor reliability normally will not be available in time for the next succeeding generation, but considerable testing and startup experience should be available and usable."

Operating experience is the information "which may lead to lower costs," and is the program objective as stated on page 4. Yet, the time schedule of the proposed program is stepped up so fast that the operating information on early reactor plants will not be available for the design of next succeeding generation of plants. Hence, they will not contribute to program objectives. Surely, the program will be changed to avoid such inconsistency.

We are unable to offer any suggestions regarding the date of 1968 set in section (b), but think you should consider the following. You state, in the last

paragraph on page 4, that there exists "generally higher cost of conventional power abroad." We wish to point out that foreign manufacturers sell equipment at lower cost than American manufacturers; so, we presume that foreign countries will achieve nuclear power competitive in cost with conventional methods of production, by using their own equipment, at an earlier date than we can achieve such a condition, if section (b) means that we will attempt to be competitive in cost using American-made equipment. If our prestige must be maintained, it appears some method must be provided whereby we can accomplish (b) ahead of foreign manufacturers.

We agree with section (c), if you strike out the last five words, namely: "particularly with regard to power." We want to fortify our position with leadership in all fields, not just in the field of power.

Question 2. We suggest that provision be made for the addition of more technical objectives, if progress on the program shows such a need in order to advance the program.

Question 3. We do not agree that category (2), under the heading, "Technological Program," on page 6, needs to include full-scale power reactors, nor should they be provided for in this proposed program, as outlined at the botton of page 7. When the reactor experiments and the prototypes show that commercially competitive power is within reach, private enterprise will build the necessary full-scale power reactor generating plants without cost to the Government. This is the goal as stated at the top of page 8, and any such construction by the Government will not meet the program objectives.

Question 4. The proposed list of reactors include a number of full-scale nuclear powerplants. For the reasons stated, these full-scale reactor powerplants should not be included in the proposed program.

Question 5. The last two paragraphs under "estimated costs," on page 9, require evaluation in the light of the last paragraph under "program objective," on page 4. The fact that the expanded program does not include reactors now under construction, or already implemented, apparently implies that the present program with followup of reactor experiments, prototypes and full-scale plants will achieve competitive power in the United States by the time it is required to supplement present energy sources. In the eyes of the committee, the preservation of our national prestige is of enough value for the United States to spend billions of dollars in addition to the programs now underway by the United States, the utility industry and the manufacturers. We believe the money should be spent in strict accordance with section I of the Atomic Energy Act of 1954, so as to "strengthen free competition in private enterprise." This should be done by amending the Atomic Energy Act of 1954, so as to provide Federal funds as a grant-in-aid of construction to reactor powerplants built by private enterprise in accordance with the "proposed expanded civilian nuclear reactor program." We believe that a large part of the cost of such plants over and above the cost of conventional plants should be paid for by the Government. If such a program is adopted, we believe the cost to the Government will be considerably greater than that set forth under the heading, "Estimated Costs," on page 9.

Question 6. The answer of the Edison Electric Institute Committee on Atomic Power carefully points out the corrections that should be made in the section headed, "Organization and Administration on Program." It also covers the section headed, "Domestic Nuclear Power Program." We request you give these suggestions careful attention.

Our company is a member of the Southwest Atomic Energy Associates, and while our project is one of those listed in table I, may I point out that ours is the only project so listed. We believe there may be other projects just as worthy of investigation, and we believe that the Atomic Energy Commission should be required to pursue those projects recommended by the Edison Electric Institute Committee on Atomic Power when supported by recommendations of its own Technical Appraisal Task Force. We fail to see how section I of the Atomic Energy Act of 1954 can be observed without some provision for adoption of the projects submitted by private enterprise.

Question 7. We have pretty well expressed our views with regard to this in our answer to question 5. While not so specifically spelled out, the Edison Electric Institute Committee on Atomic Power, in their reply to question 7, points out the need for Government assistance in the construction of the projects proposed in your proposed expanded civilian nuclear reactor program.

Yours sincerely,

J. ROBERT WELSH.

TAMPA ELECTRIC CO.,
Tampa, Fla., November 5, 1958.

JAMES T. RAMEY, ESQ.
Executive Director, Joint Committee on Atomic Energy,
Washington, D. C.

DEAR MR. RAMEY: You have requested views and comments on the Joint Committee print of August 1958, entitled "Proposed Expanded Civilian Nuclear Power Program."

There are many aspects of the program which relate to technical matters and are of primary concern to research and development or manufacturing enterprises rather than to an electric utility company. Accordingly, rather than to comment on individual items, many of which are unrelated to background of our organization, I would prefer to make some general observations.

Nuclear power has dramatized the fact that modern research and development is so costly and conducted on so broad a scale that new approaches to its support must be found by the electric industry, the electrical manufacturer, and the research organizations.

Tampa Electric Co. is a member of the Florida West Coast Nuclear Group. Our objective is to build at a cost of some $25 million a 50,000 electric kilowatts prototype of a 200,000 electric kilowatts reactor capable of operating on natural uranium. This construction program is in collaboration with a large group of other investor-owned utilities and with the AEC, which together will bear virtually the entire cost of research and development.

The construction of a prototype powerplant is a relatively new concept for an investor-owned utility, but without such large-scale prototypes the research, development, and design of improved and, therefore cheaper nuclear powerplants cannot be demonstrated.

It would appear that any nuclear-power program should recognize as a primary factor the difference—by an order of magnitude—of the cost of research and development for nuclear as contrasted to conventional powerplants. This cost differential creates new problems as well as new opportunities for solution.

However, in achieving a solution to the problems of development of nuclear power, we must be vigilant in following the traditional pattern of utilizing to the fullest possible extent our free enterprise system.

Sincerely yours,

W. C. MACINNES, *President.*

TEXAS ATOMIC ENERGY RESEARCH FOUNDATION,
Fort Worth, Tex., October 29, 1958.

Mr. JAMES T. RAMEY,
Executive Director, Joint Committee on Atomic Energy,
United States Capitol, Washington, D. C.

DEAR MR. RAMEY: This is in reply to your letter of August 21 addressed to Mr. W. A. Parish, chairman of the board of Houston Lighting & Power Co., in which you requested his views on the Joint Committee's report entitled "Proposed Expanded Civilian Nuclear Power Program." We have assumed that your letter was intended to solicit the views of the Texas Atomic Energy Research Foundation and, since I was elected president of this foundation in May of this year, I am replying to your queries in my capacity as president of the foundation, as suggested by Mr. Parish.

There is much in the program which goes beyond matters of utility economics and technical application, and so beyond the area in which our opinions would reflect our own specialized study and experience. We would, therefore, like to confine our comments rather closely to the fields of our direct concern. In this limited context we will cover the questions in the order of your letter.

1 (*a*) (*b*). We do not have sufficient information to forecast any specific time for the development of competitive nuclear power. We believe, however, that the present methods of calculating costs result in unrealistically low estimates of cost per kilowatt-hour (see appendix A), and, therefore, that the date for achievement of commercially competitive nuclear power will be later than is now generally predicted.

1 (*c*). While we are naturally in strong agreement that the United States should lead in technical progress, we believe that the disproportionate accent on electric-power generation by nuclear energy may be pointing the program away from constructive activities in other fields. It should be noted that the emphasis

on power generation has been based on the assumption that fossil fuels will, in time, be exhausted in this country, and that they are not available in some countries. While both points are obvious, it is also the case that all electric-power generation facilities in the United States use only 14 percent of the national fuel budget in the most completely power-supplied country in the world. It follows that the emphasis on electric power leaves 86 percent of the fuel problem unsolved in this country and perhaps 90 percent of it untouched in the rest of the world. We would, accordingly, propose that the components in the national fuel budget be examined in detail and that some emphasis be shifted toward the major items of use. (See appendix B.)

2. The technical objectives appear to cover certain rather specific difficulties representing the points of resistance which have developed in the present state of the art. We realize that the program is directed toward the immediate, but would like to express the hope that its magnitude will not divert support and talent from the areas of research in which many of the present specific problems may be made irrelevant by new concepts. We would consider it vastly more desirable, for example, to solve the cost problem by eliminating the need for precision rather than by gradually working down the expense of precision.

3 and 4. Our recommendations on the specific areas of work in the technological program would probably be inappropriate.

On page 8, however, where the discussion moves into economics, it is stated that the program must lead to "strictly commercial plants which are justifiable without financial assistance from the Government," and further, "the object of this program is information, not power per se." We concur in these statements, but would like to suggest that, since most of the reactor concepts in tables I and II appear to be based on the use of enriched uranium, they cannot, apparently, contribute commercial information on the cost of nuclear power unless and until the actual (commercial) cost of enrichment has been disclosed. It is generally understood that the $12,500 per kilogram [1] equivalent price on U–235, as set by the Commission, is an arbitrary figure. Our international critics have been quick to suggest that the figure is low, by amounts ranging from 2 or 3 to 1, or more. Naturally, we have no way of knowing whether the price is high or low. For the present, we consider all estimates of cost of nuclear power as interesting comparisons between types of reactors, but as being unrelated to commercial operation. We find it difficult, therefore, to assume that the projects are accordant with the objectives, which have been so wisely and constructively selected.

5. We are not in a position to evaluate the cost estimates on the reactors noted.

6. We agree that the responsibility for the program execution should be placed on the AEC.

7. In the domestic program, both as expressed in question 7 and the Joint Committee print, it seems to us that there is a serious displacement of emphasis. In table II, it is shown that private utilities have committed or started 904,000 kilowatts, or 88 percent, of the total capacity in the present program. In the 202 hearings of 1958, testimony indicated that the dollar outlay in the above commitments will be between $450 million and $500 million, of which approximately $325 million represents the excess cost of the nuclear plants over the cost of conventional plants to provide equal—and more usable—capacity. Without statistical support, it is understood that the major suppliers of utility equipment have contributed considerable sums through price guaranties and research with respect to the 904,000-kilowatt plants. The contribution to the nuclear program by private utilities and their suppliers appears then to be in the order of $400 million. Total revenues of the electric utilities in 1957 were somewhat under 2 percent of the gross national product. As stated above in response to question 1 (*c*), the electric utility industry fuel requirements are only 14 percent of the Nation's total.

We would, therefore, urge that the Joint Committee determine, on the basis of the far more conclusive data available to it, the proportions by which various sectors of the American economy are contributing to the future fuel shortage and to the total economy; that it look to each for a way to stimulate parallel devel-

[1] In the range of enrichment generally discussed.

opment on the part of the various sectors commensurate with the part being played by the electric utility companies.

The foregoing comments are intended to be constructive suggestions, and I hope will be considered in your deliberations and will be helpful to you in making sound decisions for the future of the atomic energy program for the United States. In this connection I have noted the proposed reply to your letter by Mr. Elmer L. Lindseth, chairman of Edison Electric Institute committee on atomic power, and wish to state that I believe his letter is an excellent statement of the free enterprise position from an overall industry point of view. We join with Mr. Lindseth in pledging our support toward hastening the day when atomic power will be competitive with conventional power and will take its rightful place as a source of energy within our proven free-enterprise system.

We appreciate this opportunity to comment on the August 1958 draft of the proposed expanded civilian nuclear-power program, and hope our comments will be of help to you.

Very truly yours,

J. B. THOMAS, *President.*

APPENDIX A. COST CALCULATIONS ON REACTORS

I. LOAD FACTOR

Most of the cost calculations on reactor stations assume the load factor (or plant factor) at 80 percent. The load factor of customer load on the average United States system is 66.2 percent and, with present (22.2 percent) reserve levels, the load factor on total generation plant of 135,450,000 kilowatts is 53 percent. When any machine is operated at more than 53-percent load factor, some other machines must be "backed off" to less than 53 percent to allow the favored machine to contribute more than average to the total. In this case, some of the fixed charges properly relating to the favored machine are thus distributed over the balance of the machines since their costs (at less than average load factor) are increased.

While it is true that utilities frequently operate certain conventional machines "on base load" for the few years in which they are the newest, largest or otherwise most economical sources, it is also true that each is, in turn, relegated to the peaking position on the load curve, and over the life of such a machine, it can exceed the average only by penalizing some other machine.

It follows that the only fixed charge properly distributed over the kilowatt-hours of total generation is derived by applying the percent fixed charge (which is usually taken at 14 percent) to the total dollars in generation-plant account. The appropriate accounting on a nuclear or any other machine, therefore, relates to the dollars it adds to generation plant with the related fixed charges distributed *at generation-plant load factor.*

It would appear then that a commercial comparison can be developed by multiplying the fixed charges per kilowatt-hour as shown in the usual computation by 80/53 or 1.51. If the capital-cost estimates now used are accepted as being fully adequate, the assumptions concerning load factor, as above noted, can still result in a departure from the appropriate distribution of the fixed charges. Such incorrect assumptions, in turn, result in predictions that commercially competitive costs can be achieved before actual practice will confirm them.

II. FUEL COST

Most of the cost calculations on reactor stations assume the enriched fuel inventory at the AEC figure of about $12,500 per kilogram at average enrichment levels, and develop the fuel cost per kilowatt-hour by distributing a 4 percent per year charge set by AEC on the inventory over the assumed output. However, the 4 percent figure is unrelated to the cost of commercial financing which on conventional machines is taken at 14 percent. To obtain a comparable commercial fuel cost, the usual figures should be multiplied by 14/4 to compensate for the artificial charge.

Further, since the load factor on the nuclear machine must drop to the average or below over its life, the kilowatt-hour output per year over which the 4 percent charge is distributed should be adjusted to the average and an additional factor of 80/53 should be applied.

III. TOTAL ADJUSTMENT

The total apparent fuel cost adjustment would then be:

(14/4) (80/53) or: 5.28

If, then, the customary fixed charges are multiplied by 1.51 and the fuel charges by 5.28, the derivative will be near a commercial level, subject to the accuracy of the AEC pricing of enrichment.

APPENDIX B. UNITED STATES ENERGY BUDGET 1957

	B. t. u. $\times 10^{12}$
Energy sources (thermal):	
Coal and lignite	[1] 11,370
Crude oil, domestic	[2] 14,818
Crude oil, imports	[2] 2,100
Refined imports, net	[2] 372
Natural gas and liquids	[2] 11,769
All other	[3] 700
Total	41,129
Energy use, thermal-electric generation:	
Coal (160,766 thousand short tons)	[4] 4,019
Fuel oil (79,559 thousand barrels)	[4] 477
Gas (1,338,079 million cubic feet)	[4] 1,430
Total	5,926
Electric power generation as percent—	
Of coal and lignite use	35.40
Of fuel oil use	2.82
Of gas use	12.15
Of total fuel	14.35

[1] Statistical issue, Coal Utilization.
[2] FPC statistics.
[3] Compiled, includes wood, residue, byproducts.
[4] EEI Statistical Report, 1957, table 40.

UNION ELECTRIC CO.,
St. Louis, Mo., October 31, 1958.

Mr. JAMES T. RAMEY,
Executive Director, Joint Committee on Atomic Energy,
Congress of the United States, Washington, D. C.

DEAR MR. RAMEY: As requested in your letter of August 21, 1958, I am giving herein my views and comments on the Joint Committee print entitled "Proposed Expanded Civilian Nuclear Reactor Program," dated August 1958, which was submitted with your letter.

By way of introduction I would like to say that I am vice president and chief engineer of Union Electric Co., with headquarters in St. Louis, Mo. This company has maintained an active interest in nuclear power and has been engaged in studies on the subject since first permitted to participate in 1951. At that time a study team was formed with the Monsanto Chemical Co. Subsequently, we joined with others in Nuclear Power Group, where we have continuously maintained a team for the study of nuclear power. We are a participant in the construction of the Dresden plant of the Commonwealth Edison Co., the largest all-nuclear powerplant under construction or presently proposed in the United States.

We are in the center of a low-cost fuel area and the reserves of coal satisfactory for steaming purposes are perhaps as large as those available to any other power company of equal size. We, therefore, contemplate that our system will be one of the later ones to use nuclear power at a cost competitive with our present production. Nevertheless we are interested in a nuclear-power program which will bring about, within a reasonable time, power from the atom at a cost competitive with conventional plants.

The defining of a program as attempted in the proposed expanded civilian nuclear reactor program is a difficult but desirable one. Because of the limited experience with the nuclear-power program it seems desirable to provide a program with a substantial degree of flexibility and with adequate provisions for review and reconsideration from time to time. The matter is a highly technical one and the choice as between reactor types and the particular construction to be undertaken are matters which logically belong in the hands of a group such as the Atomic Energy Commission, having adequate technical staff to determine and advise upon the technical aspects.

The Union Electric Co. is a member of the Edison Electric Institute and Mr. J. W. McAfee, president, is a member of the Edison Electric Institute Committee on Atomic Power. We have studied the reply of this committee to your letter of August 21, and concur in the comments and suggestions made therein. We strongly urge that every possible provision be made to encourage the participation of private industry in the nuclear-power program to the end that the budget of the Federal Government will be relieved of any expense in connection with this program that private citizens can and will do.

The reply from the Edison Electric Institute referred to above makes no attempt to answer your questions 2 through 5, because of their technical nature. My personal reply to these questions are as follows:

The three major objectives stated on page 4 are in general accordance with my ideas on the matter. I am not in a position to determine the reasonableness of the dates chosen, this is largely a matter of the amount we are willing to spend to achieve the goals. The shorter the time permitted the greater must be the rate of expenditure and the greater wastefulness of the program. However, I do not believe that the dates proposed are unrealistic.

In reference to fortifying the position of leadership of the United States in the eyes of the world in the peaceful applications of atomic energy, I would refer to the proceedings of the conference at Geneva, which occurred subsequent to the preparation of the nuclear-power program proposal. Indications from this meeting are that the problems which have arisen in the production of economic power from the atom have materially changed the tone of optimism which previously surrounded such conferences. Furthermore, the news reports indicate that the leadership of the United States in this important field was demonstrated rather conclusively at that meeting.

The general technical objectives stated on page 5 appear to cover the more important fields of activities quite well. I feel that it is unfortunate that in the discussion of these objectives on page 6 (or elsewhere in the booklet) no mention whatever is made of the very successful boiling water reactor plant of the General Electric Co., Pacific Gas & Electric Co. at Vallecitos, Calif.

The technological program described on pages 6, 7, and 8 seems to me to be too much compressed. The emphasis seems to be placed too heavily upon construction of reactors and insufficient time seems to be allowed between successive generations to permit factoring in experience from previous designs.

You have asked whether it is my opinion that the list of reactors shown in table 1 is the best list for "new undertakings." I feel that, at the present writing, the list is sufficiently inclusive. It is of course, as stated elsewhere, contemplated that many of these reactors will never reach the "hardware" stage, I believe that the report suggests that fatalities are likely to run to 50 percent or more. The estimated costs appear to be within a reasonable range provided that the assistance to be provided by the Atomic Energy Commission in the form of supplies of fuel, heavy water, usage of laboratories, reprocessing facilities and so forth to be provided at costs below those normally charged by the Commission are to be in addition to the costs designated on pages 8 and 9. This statement is made because of the obvious necessity for running these powerplants at heavy loads and for long periods to obtain the required technical information regardless of the fact that the operator of the plant may suffer a heavy penalty in operating and maintenance costs while so doing. It is therefore probable that it will frequently be desirable to provide fuel materials, etc., in amounts to result in operation of the plant at no great penalty to the utility.

Yours very truly,

E. L. HOUGH, *Vice President.*

UTAH POWER & LIGHT CO.,
Salt Lake City, Utah, October 20, 1958.

MR. JAMES T. RAMEY,
Executive Director, Congressional Joint Committee on Atomic Energy, Washington, D. C.

DEAR MR. RAMEY: This is in reply to your letter of August 21 propounding certain questions relative to the proposed expanded civilian nuclear reactor program.

Our company was a member of a study group of utility companies in the Rocky Mountain area together with a few industrial companies and two national service organizations from November 1954 to March of this year. During this interval the companies furnished men from their respective organizations who comprised the study group with headquarters in Idaho Falls. In March 1958 this study group was disbanded and a new group formed known as the Rocky Mountain-Pacific Nuclear Research Group among 8 utility companies in the Pacific Northwest and the Rocky Mountain areas. I am presently serving as chairman of this group. An agreement as of April 1, 1958, was entered into with General Atomic division of General Dynamics Corp. under which the utility company participants advance funds in the total amount of $287,000 a year for use by General Atomic in pursuance of its research work in the John Jay Hopkins Laboratory for Pure and Applied Science in San Diego, Calif. Most of these companies have also supplied an engineer from their organization to work with the scientists and technicians in the laboratory. No reactor construction has been undertaken nor is there presently any commitment beyond the research work.

As a member of the Edison Electric Institute committee on atomic power, I have fully subscribed to the opinions which have been expressed by that committee in support of maximum possible participation by industry, including the investor-owned utility companies, in furtherance of the nuclear power program with the hope that neither by direct congressional action nor lack of adequate effort by these companies will the final outcome be a further spread of so-called public power and particularly power generated by federally owned facilities in competition with the investor-owned companies.

This explanation is made by way of background for the following replies to your questions:

Question 1. (*a*) Every effort should be made to achieve nuclear power competitive in cost consistent with orderly solution of the technical problems involved. Sound progress is being made and I would not subscribe to the fixing of dates certain for successful results. It is quite possible that with the experience to be gained from reactor plants now operating, under construction and in advanced planning stages the requisite answers will be obtained earlier than 1970 in the United States. However, if overall generating costs in a nuclear plant competitive with thermal plants even in high-cost fuel areas by, let us say, 1967, shall not have been attained the definite commitment to the year 1970 might well be used as a reason for a crash program during the last years of the specified period which would achieve no good purpose and be wasteful of taxpayers' money.

(*b*) As to fixing the date 1968 for building competitive plants in high-cost fuel areas in other free world nations, I am not competent to express an opinion, but with such knowledge as I have I would anticipate that nuclear powerplants will be in successful operation in those countries whose industries have need for the energy, at dates prior to 1968.

(*c*) It is a fair expectation that by reason of the financial resources and the fine group of scientists, engineers, and technicians now working in the field of nuclear power, the leadership of the United States will be fortified by actual results rather than a declaration of policy. It would be futile to assume that an outfront position by the United States in a kilowatt race will mean international leadership if the construction, operation, and maintenance problems have not previously been solved by successful technology. It would, therefore, appear that fortifying our national leadership will come as a result of the future successes of our research and development efforts, which would include construction and operation of experimental, prototype, and full-scale plants. Of course we want to utilize the genius of our great organizations working with the Government laboratories to overcome the difficulties in achieving economic results and our whole history shows that this can best and earliest be done by adhering to the principles of our free American enterprise system with a minimum of governmental restraints or competition. Both the Atomic Energy Act of 1954 and the proposed program now under discussion, inferentially at

least, acknowledge this desirable procedure. In order to eliminate any doubt, however, and to strengthen the efforts of our companies, both utility and industrial, an affirmative declaration of this principle of free enterprise might well be added as a fourth program objective.

Question 2. Without qualifying as a technician it would appear that the objectives outlined in the proposed program will do for the present. The effect of purposes (*a*) to (*f*) are obviously in line with reducing costs toward competitive fuel levels. One additional objective under (*c*) might be added, that is the fabrication of a fuel element which, by long extended burnup, may so utilize the fissle materials that reprocessing and refabrication as a fuel element will not be required. Recovery of fissionable residues and development of profitable uses for the radioactive isotopes and other irradiation products in the spent fuel may be a plus factor to make such a once-through fuel element an economic possibility.

Questions 3, 4, and 5. The technical material covered by these questions is beyond my competency. A study has been made by the Technical Appraisal Task Force on Nuclear Power of the Edison Electric Institute and the findings of this committee are in a report made to the board of directors of the institute covering the status as of July 1958. Copies of this report have been sent to the Joint Committee. I respectfully suggest that this interim survey be given consideration in connection with that part of the Joint Committee program covered by these three questions.

Question 6. The basic policies (*a*), (*b*), and (*c*) on page 9 appear to give AEC too much power of direction in the field of future research and development. I believe this declaration should be aimed at wider cooperation and the inclusion of competent nongovernmental research organizations in sharing the responsibility of a base program of research and development. At the present time at least 14 reactor powerplants in addition to those already operating are being constructed or have been proposed. Some of these are to be financed jointly with AEC and others will be entirely at the cost of industrial and electric utility companies. Under the Atomic Energy Act of 1954 the AEC through its licensing controls in sections 103 and 104b can exercise supervision over the work being done by non-Federal agencies, so I am wondering if paragraph (*b*), page 9, is a desirable statement. Worded as it is it seems to place primary responsibility on AEC for conducting the work as a part of its own function. Furthermore, it does not seem to give adequate weight to research and development underway pertaining to large-scale demonstration plants which may have a decisive bearing on the advisability of constructing the full-size plants envisioned by AEC or the Joint Committee but which at the time do not reasonably appear feasible or are of less promise than plants of other characteristics. Specifically, my thought is in all three paragraphs more reliance should be placed upon the entire field of knowledge existing at the time, including research and development work conducted outside the AEC. There is also a question as to the desirability of committing the AEC to the construction of projects which by reason of lack of sufficient technological data or economic promise would not be undertaken by other agencies. It cannot be assumed that all knowledge or the soundness of final decisions over the next 10 years can be lodged either in AEC or outside agencies.

With our growing but incomplete knowledge in the atomic energy field it is important that future programing should be as flexible as possible. In this connection the legislative functions of Congress are not well adapted to the direction of a changing program so the maximum of administrative authority should be vested in the AEC, operating within the general policies and financial parameters prescribed by the Congress.

Question 7. In furtherance of the domestic program I would emphasize the desirability of carrying out the action implied in the last sentence of page 12 of the program. The point has already been made that the greatest progress will take place through the cooperative efforts of the Commission and the investor-owned industrial and electric utility companies operating with maximum freedom and incentives of our American enterprise system. The limitation placed upon Commission participation in non-Commission projects by section 169 of the 1954 act seems inadvisable and costly to taxpayers inasmuch as it may cause expenditures by the Commission that could well be made by industry. It also could result in delays in reaching the overall objectives.

The socialistic import of section 44 should be eliminated. At least two misconceptions are embodied in the so-called preference clause whereve: it appears

The first is that public agencies are operated for the benefit of all taxpayers, whereas it is an indisputable fact that all taxpayers contribute to the cost, but a very limited few are the beneficiaries of the public moneys expended in facilities of a proprietary nature. The second error is that great profits may redound to the benefit of investors through the joint expenditure of public and private funds. Actually any electric utility which may join in such cooperative construction work will be strictly limited to earning a just and reasonable return upon its own expenditures in the project. Under all the regulatory laws it can never earn on public moneys or strategic values which may exist.

Other replies to your inquiry from those actually engaged in construction of prototype or full-scale plants will have greater value than these somewhat theoretical comments of mine. I should like to conclude by saying that through many contacts with those who are working in the field of nuclear power there is greatest desire to get on with the research, development and actual construction work so as to bring into being at the earliest possible date commercially feasible nuclear powerplants. A great opportunity is offered through the promulgation of a federally sponsored program which embodies the spirit and workability of our great American free-enterprise system. Such a program is certain to provide best results.

Sincerely yours,

GEORGE M. GADSBY.

APPENDIX 4

REPLIES FROM PUBLIC AND COOPERATIVE POWER COMPANIES AND ORGANIZATIONS

(NOTE.—Page numbers and reference to tables, etc., in the following letters refer to the Joint Committee publication of August 1958, entitled, "Proposed Expanded Civilian Nuclear Power Program.")

AMERICAN PUBLIC POWER ASSOCIATION,
Washington, D. C., November 16, 1958.

MR. JAMES T. RAMEY,
Executive Director, Joint Committee on Atomic Energy,
United States Capitol, Washington, D. C.

DEAR MR. RAMEY: Thank you for your letter of November 3 requesting our comments on the proposed expanded civilian nuclear power program. I am pleased to transmit them to you in the form of a memorandum from James L. Grahl, the director of the association's atomic energy service.

Unfortunately, the association's atomic energy committee has not held a meeting since publication of the proposed program and, although a copy has been sent to each member of the committee, there will be no opportunity to obtain the committee's comments until its meeting on December 2. The suggestions made in Mr. Grahl's memorandum, however, are generally consistent with the established policies of the association and with views previously expressed by our atomic energy committee. If the committee should have addiltional comments, I shall be glad to inform you of these after its forthcoming meeting.

The Joint Committee on Atomic Energy is to be commended for undertaking to develop a statement of the objectives, policies, and content of an expanded nuclear power program. It has seemed to us that the achievements of the United States in atomic power development, significant as they have been, nevertheless have fallen short of our country's capabilities. The lack of clear and challenging objectives and of bold policies has been, in my opinion, the single most important reason for this, and I am therefore pleased that steps are being taken by the Joint Committee to correct this situation.

Sincerely,

ALEX RADIN.

Memorandum to: Alex Radin.
From: James L. Grahl.
Subject: Proposed expanded civilian nuclear power program.

The proposed expanded civilian nuclear power program published by the Joint Committee on Atomic Energy represents a valuable step forward in defining objectives and a program for the development of economic nuclear power by the United States. However, I would suggest some changes in response to the questions posed in the letter of November 3, 1958, from Mr. James T. Ramey to you.

1. The major objectives of the program

It is most important that there be a good definition of major objectives for the United States nuclear power program. The lack of clear-cut objectives, which pose a real and specific challenge to United States scientists and engineers, has been in large part responsible for the tendency of the program to drift. This opinion is widely held. The statement of objectives in the proposed program is certainly an important step toward correcting this deficiency and I believe it could be improved if (1) it were geared to a shorter time period, allowing the establishment of more precisely defined objectives; (2) it recognized the importance of nuclear power to the domestic economy; (3) it set goals sufficiently challenging to require a considerably stronger and more concerted effort than is being made; and (4) it were couched in more specific terms.

Accordingly, I would suggest revising the statement of objectives along the following lines:

"The general considerations reviewed in the introduction can be crystallized into the following objectives for the atomic power program of the United States Government:

"(*a*) Fortify the position of leadership of the United States in the eyes of the world in the peaceful applications of atomic energy, particularly with regard to power;

"(*b*) Benefit the American consumer and the general welfare of the people of the United States by the development of low-cost nuclear power, and of other peaceful applications of atomic energy;

"(*c*) Achieve and demonstrate in the United States nuclear power production at a cost of 8-mills * or less per kilowatt-hour with several different reactor types by 1964, assuming base load operation and a plutonium price of not more than $12 per gram;

"(*d*) Achieve and demonstrate in free world nations with high fuel costs nuclear power competitive in cost by 1963."

As indicated above, it is suggested that what is presently objective (*c*) in the proposed program be made objective (*a*) because it is a more general and controlling objective than the present objectives (*a*) and (*b*). The latter are essentially statements of the steps to be achieved in order to "fortify the position of leadership of the United States."

The addition of objective (b) above seems most important. The United States program surely should be oriented toward maximum benefit to the American people and used not only to strengthen our international position but also to attain early domestic economic benefits. The frequently invoked premise that we do not "need" economic nuclear energy in the United States today is too conservative an assumption. Thus, the second paragraph following the statement of objectives in the proporsed program states that "even in the United States there is a clear need for development of a new source of energy to supplement present resources."

Beyond this, there are good reasons for believing that the cost of nuclear power will be reduced below that from conventional thermal plants in many or most parts of the United States. In addition, nuclear energy offers the possibility of low-cost power with minimum dependence upon geographical location. There is a good chance that an all-out effort to develop cheap nuclear power would bring huge financial returns to the domestic economy in the long range. Why should the United States wait unnecessarily to begin the realization of such benefits?

Objective (*c*) above would substitute a specific cost figure for the phrase "competitive in cost" in objective (*a*) of the proposed program because this phrase is subject to such widely varying interpretations as not to be a very meaningful definition of a goal. Thus, if one assumes a high fuel cost location, with 90 percent load factor, a credit for plutonium of $30 per gram and public financing, the goal becomes very different than if it were assumed to mean a cost generally competitive throughout the United States, at 60 percent load factor, with a $12 per gram credit for plutonium and 15 percent fixed charges.

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*This figure may not be the proper one. It should be set on advice from reactor experts at a point which is realizable but presents a sufficient challenge to require a much more closely coordinated and determined effort than the United States is now making.

Because of the imprecision of the phrase, I am not sure that objective (*c*) as suggested above is much more ambitious than objective (*a*) in the proposed program, but believe that a more precise and more immediate target along the lines of the suggested objective (*c*) could provide better program guidance to Government and industry.

That the suggested objective (*c*) is probably a reasonable goal is illustrated, for example, by the program recently proposed by the General Electric Co. This contemplates achieving nuclear power production at less than 8.5 mills per kilowatt-hour by 1965 by an effort almost entirely financed by private industry. If the GE goal is a reasonable one for a program based leargely on private financing and the capabilities of only one reactor manufacturer, then objective (*c*) as suggested above seems a reasonable and possibly too modest goal for a program to be supported by the combined and far greater financial, technical, and industrial resources of the Government and the entire reactor equipment industry.

Whatever goals are selected should assume a more closely coordinated United States effort. In December 1957, Dr. Stuart McLain made the following observation in the course of a public address on the atomic power program:

"I believe that *if we assembled our most experienced reactor scientists and engineers into one group, we could design plants that would be nearly economic today.* Costs are high due to overly conservative designs, unrealistic specifications, use of specialized equipment and materials where not required, and lack of construction and operating experience * * *." [Emphasis supplied.]

Dr. McLain has had extensive experience in power reactor development, at one time serving as associate director of AEC's Argonne National Laboratory.

One factor which has slowed United States progress has been the dispersal of technical talent since 1954, and a failure to utilize to the fullest the AEC national laboratories in the design of prototype nuclear powerplants. The prompt organization of "task groups" of the most experienced reactor scientists and engineers to design key projects aimed at "nearly economic" power is certainly possible and warrants serious consideration.

The Canadians, with a smaller program, seem to expect more rapid progress on fuel costs than we do. In March 1958, the experienced Dr. W. B. Lewis of Atomic Energy of Canada, Ltd., confidently predicted the achievement of nuclear fuel costs of 1.5 mills per kilowatt-hour (equivalent to coal at $4 per ton), and expected in fact that Canadian technology would "do better than this" by 1962–64.

Establishing a specific target for 1964, as suggested, would force prompt action and sustained effort over the next 6 years, whereas an objective to be achieved 12 years hence, even if specific, would permit procrastination in the early years. Finally, we can determine with some confidence and precision an achievable and worthy goal for 5 to 6 years hence but it is almost impossible to be accurate about a target 12 years away in a technology with so many uncertainties.

It seems equally clear that objective (*d*) proposed above is realistic and that the overseas objective in the proposed program would fail to "fortify" United States leadership and could appear to be a decision to abandon it. Thus, the British confidently state that the 500,000-kilowatt Hinkley Point station which is now under construction will produce power at costs competitive with those of thermal stations in England in high-cost fuel areas in *1962–63*. French representatives at the recent Geneva conference stated that the construction of several natural uranium, gas-cooled reactors "have now supplied us with a host of data which confirm us in our belief that this type of reactor will, *a few years from now*, become competitive with conventional powerplants and assist in satisfying our increasing needs in electric power." [Emphasis supplied.]

In his paper (P/1624) at Geneva, Dr. Homi J. Bhabha concluded that, based upon cost studies using British industry data on a 150,000-kilowatt gas-cooled power station built in India, "the economics of nuclear power are already such as to make it competitive with coal power in most parts of India." These judgments clearly indicate that the target date of 1968 in the proposed program wholly misses the mark.

Finally, if the domestic objective as proposed above is realistic, then the suggested 1963 goal for high fuel cost foreign areas is also realistic because of the higher costs of conventional power in those locations.

2. General technical objectives

The general technical objectives seem to be well selected and well stated in the proposed program and I have no particular comments on this section.

3. Technological program

The scope of this program seems generally adequate with two reservations. First, there is no specific reference to the need for developing several types of economic small reactors (10,000–40,000 kilowatts) for the smaller utilities in the country. This is a real and legitimate need and there is evidence that with a reasonable effort nuclear plants competitive at least in high fuel cost areas could be developed within the next 5 to 6 years. However, this will not happen as long as there is little interest taken in plants in this size range. Military reactors and small experimental facilities built primarily as pilot models for large plants are not satisfactory substitute for prototype plants designed to meet the needs of the smaller utilities.

On page 7 there is a reference to the need for developing small nuclear power plants, but they are described as "industrial" plants. If this means they would be designed to meet industrial-plant requirements, they might or might not be of a design best suited to utility needs.

Enclosed is a copy of the paper (P/849) by Mr. Samuel B. Morris on the need in the United States for small power reactors at the 1955 Geneva Conference. A specific program on plants for the smaller utilities is warranted not only by domestic needs but also by the potential usefulness of such plants in various foreign countries and explicit provision for it should be made in the technological program.

My second reservation is in respect to several references dismissing kilowatts of capacity as an important consideration. Obviously, no one should advocate building reactors merely to pile up an impressive figure on nuclear capacity. However, large-scale plants have definite developmental values. Furthermore, it is widely recognized that there are important cost reductions which can be obtained only when there is sufficient reactor capacity under construction and in operation to create volume demand for fuel elements and other components.

For example, in their paper of March 1958 Cohen and Zebroski of General Electric state:

"*Increased scale of operating in the manufacture of reactor systems and components is probably the largest single source of potential cost reductions.* In principle this source of cost reductions is available to any reactor type. In reality it will apply mainly to reactors which have already demonstrated reliability, near-economic performance capabilities, and which have had the benefit of vigorous development programs. Increased scale of operation on a given reactor type brings direct reductions in engineering costs, manufacturing costs, development liquidation costs, and in contingencies. [Emphasis supplied.]

"To a lesser degree, increased scale of operation on any reactor type is helpful to other reactors where the technologies overlap. For example, all reactor types using oxide fuels will benefit from reductions in the costs of uranium conversion, powder preparation, pelletizing, and fuel fabrication."

This paper was presented to the American Power Conference on March 28, 1958. The validity of the author's observations seems self-evident. It would be most unfortunate if the transition to volume operations were to be delayed by timidity.

This point was well expressed by the editor of Nucleonics magazine in the October 1958 issue, in which he declared that:

"* * * The economic performance of reactors is related to our economy in such a complicated way that a satisfactory evaluation of particular concepts may very well be had only by trying them out on a national scale. This means that at some point along the road we are going to have to stick our necks out and choose certain concepts for large-scale development even though our choice be based on incomplete information."

4. List of reactor projects in table I

It is difficult to pass judgment on the list of additional power reactor projects in table I when the objectives of the proposed program are not entirely clear. In addition, the proposed program assumes that only half the capacity in table I will actually be built and so some unknown half of the listing is composed of phantom projects.

In general, it would seem possible to telescope the program time schedules and make more rapid progress toward economic nuclear power. For example, it would seem possible to schedule the large pressurized water reactor, the 50,000

kilowatt organic cooled reactor and the large boiling water reactor for completion during the period 1959–63. Additional plants representing succeeding "generations" could then be scheduled for 1961–64.

In line with earlier comments on the need for a small power reactor development program, there should be added to the list 3 or 4 small prototype plants of 15–40 megawatts for completion during 1959–63. These should be plants designed and built on a commercial basis and aimed rigorously at achieving minimum costs. The variable moderator boiling water reactor concept would seem to warrant consideration in this connection.

If the two small "industrial" plants listed are in fact expected to be principally for industry, then I question if they should be termed "second generation." There are no first generation "industrial" plants underway or planned. If they are primarily for the smaller utilities, then the word "industrial" should be deleted. If they are meant to meet the needs of the smaller utilities, the time schedule proposed seems reasonable if the small plants suggested above are added to the program.

5. Estimated costs

The cost estimates appear generally reasonable, although they are for a program which is too conservative. The proposed program calls for starting an additional million kilowatts of power reactor construction between now and the end of 1963. This is a modest rate for an "expanded" program. A bolder approach, with a telescoping of time schedules seems called for if we are determined to fortify the United States position of world leadership and to achieve the benefits of generally available low-cost power in the United States at an early date.

6. Organization and administration of program

The assumption by AEC of positive direction of the reactor development and power reactor demonstration programs is essential and the proposed program would bring about important improvements in this regard.

The proposed program makes a mistake, I believe, in proposing to continue to depend in the first instance almost entirely upon the "partnership" approach to initiate the design and construction of essential prototype plants. This has proved to be a halting and uncertain way in which to conduct a program. The procedures outlined in the proposed program would have the great virtue of defining AEC's responsibilities much more tightly. However, even more positive steps seem required.

In addition to experimental prototype reactors, which the Commission would finance and have built under the proposed program, a selected number of second- and third-generation plants should be scheduled definitely as Federal projects. This would provide a "hard core" of projects, selected because of their crucial importance to a rapid rate of progress, which would be free of the inevitable delays due to waiting for proposals and negotiating agreements, and would keep the responsibility for energetic prosecution of the projects in AEC's hands rather than relinquishing it to private groups having lesser financial and technical resources.

At the same time, a large part of the prototype plant program would remain available for construction under the policies and procedures outlined in the proposed program for the power demonstration reactor program. Judging by the results of the past 2 years, only a portion of the plants required over the next 5 to 7 years would be built under "partnership" arrangements anyway, and setting aside a limited number for construction as Federal plants would not in fact reduce the program carried out by the non-Federal utilities. It simply would reduce the number of instances in which AEC first waited for proposals before going ahead with the project itself.

One other change suggested is the addition of provisions for the construction of second generation reactor projects at sites of municipal, State, and rural cooperative systems with arrangements similar to the second round power demonstration program. Under the terms of the proposed program, only experimental prototypes or projects "for which no reasonable proposal has been received" could be built at municipal, State, or co-op system sites. This is not an adequate provision for small power reactor development and it is not fair treatment, in my opinion, of the consumer-owned, nonprofit utility systems in this country.

Under paragraph B.1. on page 11 of the proposed program, there should be added:

"(c) AEC-designated prototype small power reactor projects and other reactor projects necessary for developing economic plants in the 15–40 megawatt size range, with arrangements similar to those of the second round of the power demonstration program."

7. *Other types and amounts of assistance*

If the policies and procedures outlined in the proposed program were carried out, there would be no need for additional Federal subsidies to private industry "to insure meeting the objectives of the program" because the proposed program states that if private industry (with the Federal aid outlined) does not undertake the projects which are necessary, the Atomic Energy Commission will. To speculate on still further types and amounts of subsidy, as the proposed program does under "Other Considerations" on page 12, would seem to undercut the policies stated earlier in the proposed pragram. Accordingly, it would be desirable to delete the entire paragraph under "Other Considerations."

This paragraph suggests, as an alternative to the policies proposed under the domestic nuclear power program, achieving the construction of the necessary prototype and developmental plants through Federal capital financing of reactors for privately, publicly, and cooperatively owned utilities. The paragraph states that for this to be done would require "consideration of revisions of sections 44 and 169 of the Atomic Energy Act of 1954." (Sec. 44 includes provisions on the marketing and federally produced atomic power, including a form of the "preference clause," and sec. 169 is the "no subsidy" provision.)

The "revisions" contemplated doubtless refer to the preference clause; this has sometimes been described as a bar to Federal capital investments in projects sponsored by privately owned power companies. However, it is not a bar; the bar is the refusal of private power companies to market federally financed power under the preference clause. This clause is hardly an onerous burden on a utility, since all power marketed under it must be paid for at established rates and since the privately owned utilities are obtaining about as much of the power in this country marketed under the preference clause as are the consumer-owned systems.

The preference clause is an antimonopoly provision in respect to publicly financed power and, as such, should be retained, together with the no-subsidy provisions of section 169.

Rather than proposing revisions to sections 44 and 169, it would be more reasonable to ask why the acceptance of Federal funds subject to the preference clause is so distasteful to the power companies and what harmful effects are foreseen. It is of interest that AEC's contract with Duquesne Light Co. on the Shippingport plant is subject to both section 44 and section 169 of the Atomic Energy Act of 1954, yet there appears to be no prospect of imminent disaster either to the PWR or Duquesne Light.

Conclusion

It should be emphasized that a more vigorous program for the development of economic nuclear power is advocated because it would be in the general interest of the people of the United States, and not because it is thought in some way to be favorable to the advancement of public power or inimical to the interests of private power. Early development should benefit both, and the American consumer as well.

It is important, however, that a truly economic industry be developed, and that during the developmental period the establishment of built-in or hidden Federal subsidies be avoided to the extent possible. Some already exist, such as liability insurance, fuel reprocessing cost guaranties, and fuel loans at 4 percent and it would be well to avoid creating additional ones.

To establish strong and sure American leadership, a determined effort is surely required, and should be geared to a near-term goal rather than one 12 years away. Our real competitor is the U. S. S. R. That the Soviets are a real adversary is illustrated by the Zinn report of October 21, 1958, to the Joint Committee. In that report, Dr. Zinn observes of the Russian atomic-power program that:

"Perhaps the strongest impression which I have acquired is the fact that technical progress is rapid, and that it is closely coordinated with a program of building intermediate and large-scale power reactors. The fact that there are now under construction fairly large reactors involving technology which the U. S. S. R. obviously did not have in hand in 1955 indicates that the research and development supporting effort, as well as the program of reactor construction, must be large and vigorous."

Need in the United States for Small Power Reactors

By Samuel B. Morris,[1] USA

The purpose of this paper is to discuss the need for low-cost power generation in smaller-sized generating units in the United States. Some measure will be given of the potential demand that exists. Consideration will also be given to opportunities for meeting future expansion of small plants with small reactors, should it prove possible to build atomic powerplants which will economically compete with electric powerplants burning conventional fuels to supply electricity to the smaller electric systems. It will be shown that this field has broad possibilities in the many publicly owned electric and rural electric cooperative systems totaling nearly 2,900 separate independent electric utility systems and approximately 1,000 privately owned electric utilities and industrial plants in the United States.

INCREASE IN ELECTRIC POWER REQUIREMENTS

The demand for electric power in the United States is expanding at a rate so rapid as to constitute a veritable explosion in electric energy use in this Nation. This explosive growth makes it imperative that we keep pace by providing an increasing power-generating capacity to match the ever-enlarging demand. Since the beginning of this century the great increase in population in the United States has been far outstripped by the growth in central station power capacity and production, as shown in table I.

TABLE I.—*United States central station capacity and production*

Year	Population	Capacity, kilowatts in thousands	Production kilowatt-hours in millions
1900	75,994,575	[1] 1,212	[1] 2,507
1910	91,972,266	[2] 5,165	[2] 11,569
1920	105,710,620	12,714	39,405
1930	122,775,046	32,384	91,116
1940	131,669,275	39,927	141,837
1950	150,697,361	68,919	329,141
1954	163,699,000	102,520	471,609

[1] 1902.
[2] 1912.

In general this rapid growth in power requirement approaches an increase of 7 percent compounded annually, resulting in each 10 years a doubling of capacity in kilowatts and of kilowatt-hours produced to meet the needs of population and industry. The rural electric cooperative loads have been increasing 15 percent or more per annum. Population growth, it should be noted, has only averaged 1.4 percent, the total doubling in 50 years. Current increase in population exceeds 2 percent per annum. If the rate of increase in power requirements continues as in the past, we may have a total central station power production capacity in 1975 of the order of three or four hundred million kilowatts. In anticipation of such continuing growth, the Nation must find the means and methods of supplying this enormous increase in power requirements.

DEPENDENCE ON FUEL-ELECTRIC PLANTS

The United States is favored with rather large hydroelectric opportunities and the deposits of natural fossil fuels are large. At present, hydroelectric capacity accounts for 23 percent of the installed capacity and produces 23 percent of the kilowatt-hours. Although further uses of falling water will be made for additional development of hydroelectric power in the United States, the diminishing opportunity to secure new sites and the increasing cost of such development indicates that hydroelectric power, already furnishing a minor percentage of total power requirements, will in the future furnish an ever-smaller percentage of central station power requirements in the United States. Thus, except for the potential of competitive cost power from the atom, there will be increasing demands on the fossil fuels—gas, oil, and coal, and possibly oil shale.

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[1] General manager and chief engineer, Department of Water and Power, City of Los Angeles, Calif., United States of America.

Gas and oil currently meet 35 percent of the Nation's fuel-fired central station energy. The proven reserves extend for only a couple of decades. No doubt additional discoveries will lengthen this period. Although currently oil reserves are still being discovered at the rate of 1.6 barrels for every barrel consumed, this fortunate condition is not expected to continue very long and is largely offset by increased uses. In the lifetime of nations and their peoples, the time is truly short in which dependence can be made on oil and gas.

These fuels should, if possible, be conserved for their many special premium uses rather than be consumed in central station powerplants. Our coal deposits, however, will last longer—many times longer—but do not approach the future requirements of man in this area of the earth. Coal production is at ever increasing cost.

Among the premium uses of oil, one is to operate diesel-electric plants. These are more commonly in use by the small electric utility, especially those operated by municipalities and rural cooperatives.

HOPE FOR ATOMIC-REACTOR-ELECTRIC PLANTS

With potential uranium and thorium reserves already estimated to provide energy 23 times that of coal, the use of atomic energy for peaceful purposes offers bright promise for meeting this increasing need. The United States is intensifying its effort to develop practical atomic reactors for economic production of electric power. Everyone is agreed upon the great magnitude of the opportunity. The Government, industry, and the people are pressing hopefully for more speed in accomplishment of these goals. Up to the present time, however, the important field of small reactors has largely been neglected.

UNITED STATES PROGRAM AIMED AT LARGER REACTORS

The United States Atomic Energy Commission in 1954, only 15 years after nuclear fission of uranium was accomplished, embarked upon a developmental program involving 5 separate reactor experiments. Each will produce sizable amounts of heat available for conversion to electrical energy by standard station turbine-generator equipment. One of these is to generate as much as 60,000 kilowatts of electricity.

Most of this developmental work on nuclear reactors relates to those of 75,000 to 100,000 kilowatts or more. True, several reactors under development are only of 5,000 kilowatt capacity, but they are prototypes for large reactors and are not designed to operate efficiently and economically at 5,000 kilowatts nor to develop most effective criteria for design of small reactors of the range from 5,000 to 75,000 kilowatts.

The developmental program is already being expanded and the United States Atomic Energy Commission has announced its intention to add two new reactors to its program. This will bring to seven the number of reactors, each testing a different fundamental concept of production of heat energy for conversion into electricity by conventional or modified turbogenerator methods.

Already there are five proposals for large-scale atomic reactors submitted to the United States Atomic Energy Commission by electric utilities either singly or in groups. Four are in behalf of privately owned utilities and one is by a publicly owned utility. These vary in size from 75,000 kilowatts to 236,000 kilowatts capacity and total nearly 700,000 kilowatts. None of these offers are by the smaller utilities and none are for small reactors between 5,000 and 75,000 kilowatts.

TABLE II.—*Number and capacity of small electric systems in the United States*

System capacity in megawatts	½ system capacity unit in megawatts	Number of systems			1953 total capacity in megawatts		
		Private	Public	Total	Private	Public	Total
10 or less	5 or less	124	838	962	336	2,201	2,537
11 to 30	6 to 15	33	75	108	623	1,506	2,129
31 to 70	16 to 35	32	21	53	1,564	930	2,494
71 to 150	36 to 75	25	10	35	2,698	1,120	3,818
Total		214	944	1,158	5,221	5,757	10,978
Average system capacity					24	6	10

PRESENT DEMAND FOR SMALL FUEL-ELECTRIC GENERATION UNITS

There are approximately 1,900 municipally owned electric systems and 1,000 rural electric cooperatives in the United States, making a combined total of 2,900. The central station need for small reactors, if they prove to be economical, will arise largely from this field. The privately owned electric systems are generally much larger and each generally serves many cities. However, they also have many small generating plants, located near minor load centers to reduce transmission costs.

The following table gives an estimate of the number of small electric systems in the United States in the year 1953 which had individual system capacities of less than 150,000 kilowatts and which may use generating units of 75,000 kilowatts or less.

In order to secure an estimate of the market for additional small generating units in the public and private utility systems of the United States, it is assumed when economical so to do, that each utility would install a unit of one-half its total system capacity. It is on this basis that the table below has been prepared.

This is a sizable total generating capacity representing about 12 percent of the total central station generating capacity in the United States in 1953. On the basis of installation of units of half-system capacity, as explained, the potential number of units that might be installed in the decade following 1953 would be approximately 1,160 with an average capacity of 10,000 kilowatts. On the basis of the historic doubling of capacity in 10 years, we could reasonably expect that there would be a requirement by 1973 for at least 1,160 units of average capacity of 20,000 kilowatts. This stage would be as early as reactor development might become a major factor as a new power generating source in the electrical utility field. This estimate does not include replacements which, if considered, would extend the opportunity for new power units. If they were of greater economy, such replacements would unquestionably be accelerated.

There are, in addition, industrial plants reporting to the Federal Power Commission, of which nearly 60 percent are interconnected with electric utility systems.

TABLE III.—*Small industrial plants*

Plant [1] capacity in megawatts	Number of industrial plants	1953 total capacity in megawatts	Average plant capacity in megawatts
Interconnected plants:			
5 or less	276	663	Less than 3
6 to 15	97	938	10
16 to 35	65	1,544	24
36 to 75	24	1,179	49
Total	462	4,324	9
Over 75	12	1,651	138
Total interconnected	474	5,975	12.6
Plants not interconnected	326	9,877	30.3
Total industrial plants covering 85 percent of industry production	800	15,852	20

[1] It is assumed that unit replacements of industrial plants would duplicate the existing plant capacity, as these plants generally do not provide their own reserve capacity.

Of the 474 interconnected industrial plants, only 12 are larger than 75,000 kilowatts. Detailed information is not available on plants not interconnected. However, since the average capacity of the total noninterconnected industrial plants is 30,300 kilowatts as compared with 12,600 kilowatts for the interconnected plants, it is obvious that the number of smaller plants is somewhat less than the total of 800 reporting to the Federal Power Commission, but may easily total 750 smaller industrial plants.

In summary, it is estimated that the small electric systems and industrial plans having potential need for generators of 75,000 kilowatts or less total nearly 2,000 as follows:

	Plants
Publicly owned systems	944
Privately owned systems	214
Industrial plants	750
Total	1,908

THE CASE FOR RESEARCH AND DEVELOPMENT OF SMALLER REACTORS

It is no doubt true that larger nuclear reactors will cost less per kilowatt to build and less per kilowatt-hour to operate than the smaller reactors. However, the latter may sooner be able to achieve a competitive position in relation to small fuel-fired steam-electric or diesel-electric units because such small conventional units are less economic power producers than the large steam-electric units of 75,000 to 250,000 kilowatts. The number of small units of fuel-electric generators is many times the number of large units. There is therefore a much greater opportunity for economy in development and repetitive manufacture of many small units. This should be a factor in their competitive position.

The cost per kilowatt-hour for operation of the smaller present generating units, incluing capital charges, is generally from 8 to 15 mills; for the larger modern units, from 4 to 8 mills. Accordingly, small atomic reactors producing power at 6 to 8 mills or more would be competitive with the present small central station unit. Large reactors, however, would have to produce power at 4 to 6 mills, or somewhat higher in high fuel cost areas, to compete with up-to-date fuel-steam-electric units of 75,000 to 250,000 kilowatts.

The utilities and industries using these small units are generally less able to contribute the high costs of research associated with atomic energy developments, so it would appear that Government aid should not be confined to the large reactors only but should include research on small reactors also.

Assistance to the small city, rural cooperative or corporation permitting it to reduce its energy costs so as to sustain its operation and be in a better position to provide electric power at competitive cost for its cusomers is sound philosophy and economy for he Nation. Experiments in these smaller installations would serve as the pilot plant steps for larger reactors to be developed for the larger of these small utilities.

PUBLIC AGENCIES AND COOPERATIVES BORROW AT LOW INTEREST RATES

The lower cost of borrowing funds for capital investment by municipalities and rural cooperatives must not be overlooked. Under present Federal policy, existing for more than 20 years, rural cooperatives are loaned money at 2 percent interest repayable in 40 years. The average municipality, with its ability to issue tax-exempt bonds, is able to borrow funds at 2.25 to 2.75 percent for 40-year serial bonds, while even the large corporations must pay 3.0 to 3.5 percent for funds to build their larger steam-generating plants. This favorable position of public agencies and rural cooperatives should be of material assistance in enabling them to invest larger sums to secure low operating costs and thus to improve the competitive position of smaller reactors.

DEVELOPMENT FROM SMALL TO LARGE EQUIPMENT IS NORMAL COURSE

The steam turbine came into use at the turn of the century and since then has been generally adopted for large central power stations. For the first 3 decades, substantially all of the units installed were what we would now refer to as smaller units, those of less than 75,000 kilowatts.

It is only in the past 2½ decades that larger units have come into use and only 1 decade since more than a handful of units larger than 100,000 kilowatts have been installed.

If it were not for the great economy of these very large units operating at high temperatures and pressures and with reheat cycles, it is quite likely that the aim of atomic power reactor development would have begun with smaller reactors and then with experience have worked up to the very large reactors.

Throughout industry and the entire engineering world, it has been common practice to begin with smaller units and, as they successfully prove themselves, to go to larger and larger units. This is true whether it be ships, trains, dredges, dams, or powerplants. In an industry only a decade old, minds must be kept open and adequate study, research, and development given to the possibilities of a small reactor which would compete economically in this important field. As an illustration of changing attitude, the writer participated with a group in 1953 who were told by the Chairman of the United States Atomic Energy Commission that reactors must be over 100,000 kilowatts to be of any likely economic worth. A year later the position of the small reactor appeared more hopeful to the Director of Reactor Development of the Atomic Energy Commission.

LARGE POTENTIAL MARKET FOR SMALL REACTORS

The manufacturer able to develop and produce small reactors of 5,000 to 15,000, 16,000 to 35,000, and 36,000 to 75,000 kilowatts will meet an important need in central station generation for small electric systems, especially municipal and rural cooperative systems. His small reactor should also find increasing local markets at mines and other dispersed industries.

While not within the scope of this paper, it may be mentioned that the manufacturing and marketing of small reactors should prove of great economic and social value, not only in the United States but in remote and presently undeveloped areas of the world. In fact, in most of these areas there is little or no opportunity for economic use of a large reactor. The opportunity will be for small reactors, for the markets for power are yet to be developed. Otherwise these sparse markets must be met by waterpower, if available, or by small conventional fuel units. Transportation of conventional fuel requirements to develop such new electric power markets in the undeveloped areas presents difficult and expensive operations.

SUMMARY

These apparent needs and opportunities for smaller reactors under 75,000 kilowatts emphasize the importance of greatly intensifying developmental work in this field. Indicated advantages of small reactors for municipalities, rural electric cooperatives, and other public agencies include the low-financing cost, which should reduce the capital carrying cost of their plants. Increasing price of diesel oils and their possible future shortage is faced by many small cities and rural electric cooperatives dependent upon diesel-electric plants.

The National Rural Electric Cooperative Association and the American Public Power Association, having a great majority of their members operating small units, are increasingly aware of the need to stimulate further development of smaller atomic reactors and are doing something about it, either through the establishment of study teams or the negotiation of "access agreements" with the United States Atomic Energy Commission.

These opportunities for service by smaller atomic reactors to meet the fast increasing power requirements of a large segment of the Nation's population and industry present a challenge which cannot be neglected or ignored. Finding the methods and means for supplying the expanding electric energy needs, not only of the smaller population units of the United States but also those in other regions of the world where the small atomic powerplants can bring rapid advances in standards of living will rank high among the important benefits to be achieved through the peaceful uses of atomic energy.

STATE OF CALIFORNIA,
DEPARTMENT OF WATER RESOURCES,
Sacramento, Calif., October 17, 1958.

Mr. JAMES T. RAMEY,
Executive Director, Joint Committee on Atomic Energy,
Washington, D. C.

DEAR MR. RAMEY: This is in response to your letter of August 21, 1958, to Mr. M. J. Shelton, deputy director of this department, requesting our views and comments on the Joint Committee print titled "Proposed Expanded Civilian Nuclear Reactor Program."

At the outset it may be appropriate to review this department's general position relative to future energy demands and the anticipated application of nuclear power to help meet those demands. The State of California, through this department, is engaged in the formation of a comprehensive water-development program designed to meet the predicted ultimate water needs of the State. An integral part of this program is the determination of optimum economic systems for the supply and use of energy within the many water projects destined to become part of the total plan.

The first unit in the plan, the Feather River project, will require vast amounts of energy for pumping. As ultimately developed by about 1990, the net consumption of electrical energy may exceed an annual rate of 5 billion kilowatthours. Even greater energy demands will appear as the entire California water plan is developed, in addition to growing needs for industry, municipalities, and agriculture. Inasmuch as the first units of the Feather River project are tentatively planned to start operating by about 1965, and considering that a substantial

part of California's energy needs is already being supplied by importations of gas and oil it is evident that we have a very real concern in the early achievement of economic nuclear power.

With respect to your specific questions, we wish to offer the following comments, numbered to correspond to your questions:

1. We agree in principle with the three major objectives of the program. It would seem that the dates mentioned for competitive nuclear power, i. e., 1970 for the United States and 1968 for allied nations, are consistent and represent a reasonable compromise between an earlier date attainable only by costly acceleration of research, design, and construction, and a later date projected further into the period of growing scarcity of conventional fuels and accompanying higher costs. The 1970 goal may be said to tie in generally with the timing of our requirements. While reserves of fossil fuels in the West are adequate for many years to come, the cost trend is likely to be upward and benefits should accrue to our program by early achievement of competitive atomic power.

The earlier goal in foreign countries seems attainable on the basis of their generally higher energy costs. It would seem, too, that in extending our program to demonstration of competitive nuclear power in other free world nations, competition in reactor development by those nations would be stimulated, leading to beneficial exchange of information and more rapid worldwide progress in the art.

A suggestion is made regarding the statement of objectives in terms of the expression "nuclear power competitive in cost." This will mean a certain cost per kilowatt-hour in one part of the United States and a substantially different cost in another. The differences, being due mainly to fuel costs, would not be reflected to the same extent in nuclear plants. Even within different areas in California, power costs differ by around two mills per kilowatt-hour. For example, Pacific Gas & Electric has announced that its proposed 60,000-kilowatt nuclear powerplant to be built near Eureka, Calif., will achieve competitive power (with the second core) at about 8 mills per kilowatt-hour. To be competitive in the Los Angeles area, however, nuclear power costs would have to be in the neighborhood of 6 mills. Inasmuch as the objectives of the program will undoubtedly serve as guideposts and have important influence on legislative and budgetary actions affecting the program it is felt that "competitive power cost" should be specifically defined numerically, with a standard load factor and method of financing. Not only would this make it independent of variations arising from geographical location but it would provide a definite measuring stick to compare accomplishments with different reactor concepts. It is granted that we do not know what "competitive" power costs will be in 1970, or even in 1965, but the figure can be revised through the development period as deemed necessary.

2. The 10 general technical objectives appear to cover all of the features of reactor development in most need of improved performance and lower cost. One further nontechnical objective might be an integrated attempt to develop a pool of scientists and engineers as well as skilled operators and technicians. This should result to some extent through normal procedures but a concerted effort by those directing the program could assure with certainty an adequate supply of technical personnel for future nuclear system expansion.

3. The technological program seems quite comprehensive in scope. However, it is believed that low temperature process heat reactors might justifiably be given greater emphasis. It is possible during the period of the proposed program that economically feasible saline water conversion systems of the distillation type will be demonstrated. Characteristics of such systems, i. e., large size and high load factor, point toward the application of nuclear heat sources as a means of reducing energy costs. Numerous other potential markets exist for process steam, of course, particularly in manufacturing processes. While a process heat reactor is included in the proposed program, it is of small size compared to heat requirements for salt-water conversion plants. Possibly each, or at least an appropriate few, of the reactor types proposed for study might be considered candidates for process heat application and could, with a small amount of additional effort during design and development, be analyzed in terms of industrial process heat and salt-water conversion applications.

During the course of the program each reactor system under study will have to be tested against the current status and the future trend of conventional technology and economics to determine its probable competitive position. This must be done to determine from an economic standpoint the desirability of building the reactor. Since this implies a detailed knowledge of the present and future energy market it seems appropriate to describe within the scope of the technological program a system of continuing energy economics analysis.

The results of the program would be as a result more meaningful and readily understood by all parties.

4 and 5. We do not feel competent to comment on these two questions.

6. The proposed policies on organization and administration of the program appear to be sound and capable of achieving the objectives of the program.

7. We do not have any specific recommendations on types and amounts of assistance.

Thank you for the opportunity of commenting upon the proposed reactor program.

Very truly yours,

HARVEY O. BANKS, *Director.*

CONSUMERS PUBLIC POWER DISTRICT,
Columbus, Nebr., October 31, 1958.

Subject: Proposed expanded civilian nuclear reactor program

Mr. JAMES T. RAMEY,
Executive Director, Joint Committee on Atomic Energy,
Washington, D. C.

DEAR MR. RAMEY: Listed below are the comments prepared by Consumers Public Power District in connection with the questions posed in your letter of August 21, 1958, regarding the proposed expanded civilian nuclear reactor program, as prepared by the staff of the Joint Committee on Atomic Energy. The numbered paragraphs correspond to your questions:

1. The objective to "achieve and demonstrate in the United States nuclear power competitive in cost per kilowatt-hour by 1970" should include some reference as to the policy of obtaining this goal with—

(*a*) several reactor types, or

(*b*) by continually discarding those systems which have a lesser chance of being the cheapest.

Although the tone of the proposed program indicates that several reactor concepts should be carried through to completion, I believe it should be stated as an objective.

In addition, it seems necessary that the words "competitive in costs" be further defined by stating the areas in the United States, or range of fossil-fuel cost, where such tests are to be applied. The fossil-fuel cost when combined with fossil-fueled plant efficiencies, operating costs, and financing costs establishes a yardstick against which our progress may be measured. A different yardstick could be applied to the free-world nations.

2. Many of the general technical objectives are directed toward lower fuel costs (i. e., better performance, higher efficiencies, etc.) or toward cheaper capital costs (i. e., cheaper components, field assembly, etc.). A third significant element which should be considered is the investigation of methods and designs which will result in lower daily operating costs (i. e., reduced maintenance frequency, reduced operating personnel requirements, ease of maintenance, etc.).

3. The program should contain some guide as to the overall policy for proceeding, timewise, in successive steps, such as first- or second-generation reactors for any particular reactor concept. There will be a material time difference in reaching the main objectives, depending upon whether successive steps are taken only after full and extended operation of a research or experimental reactor, or whether they are taken as rapidly as possible consistent with the prospects of success gained from a more limited operating period.

4. In all probability, table I represents the best list of reactors for this program as of today. However, the rapid technological developments would seem to require a yearly reevaluation of this list.

5. The cost estimates for construction appear low, in view of our experience and in view of the long-range character of the program. A 100-megawatt installation may approach $600 per kilowatt and, according to the Engineering News-Record construction cost index, this $600 construction cost base may increase at approximately 5 percent per year. For 1 million kilowatts, the entire construction effort may reach a base cost of $600 million, with a potential increase of $300 million.

The design and development costs would be subject to the same increased cost associated with an expanding economy.

6. We agree that it is necessary for the AEC to retain and aggressively carry out the direction of the program, including the selection of locations, designs, capabilities, and other technical decisions concerning the Federal Government's program.

7. Research and development assistance has been difficult to administer in view of the fact that there is no clear-cut definition of research and development.

Those costs, which are beyond the cost of power from an electric utility's modern fossil-fueled powerplant, are expended to gain information. The value of this basic information accrues to the Nation as a whole and should be considered as a research and development cost. However, to apply these funds to any one portion of the powerplant operation will prejudice the remaining operations. For example, to apply the funds to daily operations will tend to invite the manufacturer to build the plant as cheaply as possible and incur higher operating costs, since these would be reimbursable in part. To apply these funds to artificially lower fuel costs may result in sacrificing fuel efficiency in order to save initial investment. To apply these funds to the initial investment may result in an overdesigned plant with an artificially lower operating cost.

These conflicts may be minimized if the funds are used to defray some predetermined percentage of these excess costs, thereby retaining the incentive to build an optimized powerplant.

This specialized definition of research and development may be applied to a process heat plant or to a 200-megawatt electric powerplant, operated by either public or private utilities. In addition, it would tend to minimize the influence of AEC policy on reactor design, as could be experienced with a changing fuel-pricing policy.

We appreciate the opportunity to comment on the proposed program, and, if further amplification of any of our comments is desired, please advise.

Very truly yours,

R. L. SCHACHT, *General Manager.*

DEPARTMENT OF WATER AND POWER,
THE CITY OF LOS ANGELES,
September 22, 1958.

Subject: Proposed expanded civilian nuclear reactor program.

Mr. JAMES T. RAMEY,
Executive Director, Joint Committee on Atomic Energy,
Congress of the United States, Washington, D. C.

DEAR MR. RAMEY: This is in answer to your inquiry of August 21, 1958, regarding our views and comments on the proposed expanded civilian nuclear reactor program by the Joint Committee on Atomic Energy.

1. We are in general agreement with the three major objectives of the program (p. 4), but believe that a more precise definition of "competitive nuclear power in the United States" might be helpful. We suggest the following elaboration: Competitive nuclear power in high-cost regions of the United States (California, Florida, and New England) over the life of the plant, and based on private financing.

2. The general technical objectives (p. 5) are adequate, except that special emphasis should be placed on such items as (*a*) cheaper components; (*b*) cheaper field assemblies; and (*c*) better fuel elements, for already proven concepts.

3. The scope of the technological program (p. 6) is more than adequate. The programs specified for unproven concepts are too ambitious for the present state of development of these concepts. It is believed that these unproven designs should be held to the status of research and development work rather than the building of prototypes or full-scale reactors before the detailed engineering problems such as corrosion, fuel stability, and control are fully developed. The moneys designated for these unproven designs should be diverted toward second- and third-generation plants of the proven variety.

4. In our opinion, the following reactor plants should be undertaken (table 1):
Gas cooled graphite moderated
Boiling water with nuclear superheat
Process heat reactor
Intermediate energy neutron breeder
Water cooled, graphite moderated Hanford type
Pressurized water enriched uranium fuel
Boiling water enriched uranium fuel
Organic cooled reactor
High temperature gas cooled, graphite or heavy water moderated
Sodium cooled fast or intermediate breeder.

The reactors eliminated from table 1 would be given enough consideration so that research and development may be progressed along the lines most needed for that project, and this should be done in our national laboratories or under contract with a university.

5. We believe that the cost estimate (p. 8) is adequate. However, it might be reduced for second- and third-generation reactors of proven design.

6. We wholeheartedly endorse the basic policy of the program (p. 9) that the AEC must provide positive leadership to make certain that the objectives are achieved in terms of practical results. This would include the following:

(*a*) Research and development.

(*b*) Positive direction of the reactor development program.

(*c*) Selection of the reactors to be designed and, in case a proposal to build is not received, construction by the AEC.

The above might help bring an increased participation by private industry in the program.

We further believe that long-range guaranties (15 years) of plutonium buy-back prices will implement the basic policy of the program.

7. The role of the municipal or cooperative-owned utilities is not too clear from the present wording. It may be construed that the municipal and cooperative-owned utilities would only become a part of the program by default of privately owned utilities.

We believe that an extension of the second round proposal conditions will be helpful to the domestic program.

We appreciate having the opportunity to comment on your committee's proposal, and hope that our comments will stimulate your review.

Sincerely,

WM. S. PETERSON,
General Manager and Chief Engineer.

NATIONAL RURAL ELECTRIC COOPERATIVE ASSOCIATION,
Washington, D. C., November 24, 1958.

Mr. JAMES T. RAMEY,
Executive Director, Joint Committee on Atomic Energy,
The Capitol, Washington, D. C.

DEAR MR. RAMEY: We appreciate the opportunity to comment on the proposed atomic-energy program set forth in the Joint Committee on Atomic Energy print entitled "Proposed Expanded Civilian Nuclear Power Program." While the statements set forth below have not been reviewed by either NRECA's atomic-energy committee or the membership at large, we believe you will find them in keeping with policy statements set forth by the association's membership over the past several years.

In keeping with your request, we will direct our comments to the specific questions you raise in your letter of November 4, 1958.

We would argue on the basis of the achievements being made in the rest of the world that, in our opinion, your third objective to "fortify the position of leadership of the United States * * *," by definition, contains an inherent impossibility due to the goals set forth in the first two objectives. With the rapid progress being made by the U. S. S. R., Canada, Great Britain, and the full participation of other nations in this program who are relatively "newcomers," such as India, we cannot agree that the establishment of a goal by 1970 for competitive nuclear power in the United States or competitive nuclear power in the "high cost" power nations of the world by 1968 will allow for the maintenance of a position of leadership by the United States in the peaceful application of nuclear power.

In reference to your second question concerning the general technical objective of the Joint Committee's proposed program, we do not feel competent to comment, except to say in general that the objectives as set forth appear adequate and well chosen.

Your third question calls for comment on the adequacy of the scope of the technological program as set forth. Restricting our comment to our basic needs and desire to participate in the nuclear-power program, we must at this point voice strong objection to the lack of specific reference in your proposals for the development of several types of smaller reactors in the 10,000 to 40,000 kilowatt range for use by the rural electric cooperatives, municipalities, and public-utility districts in the country.

Secondly, failure to include reactors of this size in your proposals largely negates the spirit and letter of your second (*b*) objective, since it is our impression that many of the nations of the world will require reactors in this specifically mentioned size range.

Further, we should like to comment on your remarks in this section which states that "* * * the object of this program is information, not power per se." Such an approach, we believe, would at best hamper and at worst preclude the rapid development of competitive power from nuclear reactors which we feel is a must of any nuclear power program. We believe, as has been expressed in many circles, that only through the construction and operation of a sufficient number of type and size of reactors, demanding a large volume of fuel elements and other components, can it be hoped to in any way substantially reduce the various costs incurred in the manufacture of reactors systems and their components.

Concerning your fourth question, we would again comment that your proposed list of reactors is lacking due to the exclusion of several small reactor projects in the 10 to 40 megawatts class. This is assuming, of course, that the two "industrial plants" listed are for that purpose and not for the use of small utilities.

Aso, concerning the fourth question we feel that the time schedule set forth in table I is rather conservative, and that in keeping with the objectives set forth (objective (*c*) primarily) the reactor development could and should be greatly accelerated in relation specifically to the schedule set forth in table I.

We do not feel competent to comment on the reasonableness of your cost estimates, but in keeping with our position on accelerating the program, we would suggest greater expenditures in the immediate future.

Your sixth question calls for comment on the proposed policies on organization and administration of the nuclear-energy program. We have always felt that the AEC should exert much more forceful and positive direction of the reactor development program, and have always believed that this was an essential factor necessary to provide worldwide leadership in this most important new technological field. However, we do not believe that the "partnership" approach as set forth in the proposal can achieve the above-mentioned goal. To date, this approach has led to little more than a roadblock in the way of progress. We believe that the Federal Government should have a more important role to play in this program than that which you outline.

We believe that the consummation of several Federal projects as envisioned in the Gore-Monroney-Holifield bill of the last session of Congress would have gone a long way in paving the way for a successful nuclear energy program in this country. We do not feel, as some have argued, that such an approach would in anyway curtail or inhibit the participation of private groups in the program; to the contrary, we believe greater stimulus would be provided to these groups by the direct construction and operation of Federal reactors.

Further, as representatives of the rural electric cooperatives, we take strong exception to the proposal which provides that only experimental prototypes or projects for which no reasonable proposals have been received could be built at municipal, State, or cooperative system sites. This, we believe, would effectively exclude consumer-owned electric utilities for actively participating in the nuclear power program, and further, help create a monopolization of the program by the commercial electric utilities.

In answer to your last question, we would say that the proposals you outline under "Other Considerations" go a long way in precluding participation in the program by the Federal Government. This proposal strikes us as somewhat illogical, since you first outline a program for private participation, with Federal aids, and then propose Federal construction and operation if no private participation ensues. Then the proposals turn to consideration of additional sub-

sidies if private participation is lacking, thereby, effectively eliminating the previous conditions of the proposals.

Further, concerning this last proposal, we strongly oppose any proposal which seeks to amend or revise sections 44 and 169 of the Atomic Energy Act of 1954. We do not believe that experience has shown that either of these two sections of the Atomic Energy Act have in any way hampered the atomic energy program.

We believe the above comments covers our thoughts on your proposed program. We sincerely hope they will be given consideration in your deliberations. Of course, we would be happy to expound on any of the thoughts we have outlined here. If not before, we assume we will be given this opportunity at the next Joint Committee on Atomic Energy 202 hearings.

Respectfully yours,

PAUL NELSON, *Staff Economist.*

RURAL COOPERATIVE POWER ASSOCIATION,
Elk River, Minn.

Mr. JAMES T. RAMEY,
Executive Director, Joint Committee on Atomic Energy,
Congress of the United States, Washington, D. C.

DEAR MR. RAMEY: We are pleased with the opportunity presented by Congressman Durham and Senator Anderson to review the suggested proposed atomic-power program and to comment on it. First, these comments are my own personal ones and do not represent a policy statement of our directors.

First, may I comment on the committee's actions in regard to our proposal. While we were at that time concerned in a change of rules in respect to contracting, we would be remiss in our duties if we did not convey to the Commission our sincere appreciation for the fast and practical handling they gave to our proposal, and we want to express our appreciation for their actions in getting our program started.

I will review your items as listed.

Item 1. Item (*a*) and item (*b*) can both be done in the United States as opposed to separating the two areas in the achievement of power costs. There are many areas in the United States where nuclear power can be made competitive with other type fuels and, if activity is centered in these areas, the foreign objective would also be taken care of, with results that American manufacturers and engineers would be further improved by the crystallization of these activities in our country. Such operations could still be compared with power costs in foreign markets.

Your item (*c*) establishes a responsibility of the United States as in charge of sales of atomic energy and, particularly, with regard to power.

Item 2. Generally, we would agree that your technical objectives on page 5 are important areas for improvement and development of the art; however, one must recognize that construction of plants under present safeguard requirements is not telling us very much about investment per kilowatt costs. Such a plant or two should be built in an area of the country and be of such type plant that those facilities dedicated to safeguard could be minimized and reduced to no more than are presently needed in a conventional plant. We are keeping our safety factor on meters high, we are paying high costs for containment. This is helping us to obtain your item (*a*) when we are attempting to engineer up to realistic safety factors. It is recognized that a power accident would set the program back a great deal; that is why I suggest construction be made in an area where such facilities are not necessary, so that figures can be obtained more realistically following conventional practices. We would, thus, more definitely establish what failures must be guarded against and which failures can be tolerated from the standpoint of affecting the environment.

Item 3. The suggested program for development on page 6 is an excellent approach to the problem. It needs only equal purpose on the part of the program administrators and it needs incentive. By this I mean if private capital finances these plans or if Government capital finances such plans, some guaranties should be made to protect the contractor, whether he be a utility, a municipal, or a cooperative. At the same time, the operator should be permitted to take advantage of the lower costs that he may be able to achieve. The American system has grown great because of incentives. We feel, personally, one serious drawback to our contract is the no-risk, no-profit philosophy. It is our dedicated intentions to make our plant run as cheaply as humanly possible, but we still be-

lieve that the industry as a whole would be more rapidly improved if all others who are involved in the ownership and/or operating responsibility of these plants could have cheaper power than conventional as soon as they can bring such results about, instead of being faced with the policy that, because there is a dollar of Government money in the project, they can obtain no better results economically than conventional operating costs.

Item 5. As to reasonableness of cost estimates of plants, until the safeguard committee is able to release their requirements through experience it will be extremely difficult to improve any cost per kilowatt. Many factors will continue to keep atomic kilowatt costs high until a more realistic approach can be assumed in reviewing these matters.

Item 6. I would agree with your policies for organization and administration of the program, but it should be completely divorced from the status quo economics of powerplants other than their influence as a goal. The REA made some very great strides in reducing the cost of constructing distribution lines in the United States and pointed the way to the utility industry to move up in voltage and down in cost per customer, which is reflecting lower power costs to utility consumers as well as REA consumers, because they did not allow the values to determine their program's goals. These considerations should be only to implement the administrative program and not to restrain.

Item 7. I believe your suggestion for the several methods of assistance would be quite adequate. The size of the project, however, limits the selection of contractors between investor-owned and municipal- or cooperative-owned systems. In this area, it appears difficult to the writer to expect the rate payers of an electric system to support completely the experimental operating costs which would be operating expenses as well as those costs in excess of conventional equipment. Few, if any, organizations desire to experiment with small plants whose operating experience does not scale up accurately. Few small electric suppliers can afford the big plants, and most municipals and cooperatives cannot afford risk capital at all. Examination of the source of risk capital on the large plants discloses that substantially more money comes from taxes not paid, and so are still, to a large extent, Government financed. Basically, the Government program should consider the high stakes involved both from domestic savings by improved power costs, as well as all of the components of international relationship in this field. A program involving $2 billion or $3 billion to subsidize the high operating costs, the high capital costs, distributed between investor-owned and consumer-owned organizations is a relatively small price to pay for the goals that can be achieved, in both our domestic and international areas, and any program should, as described before, permit the operator to receive the benefits of the lower operating costs.

It will take money to do this job rapidly, just as the budget was adjusted several times for the Shippingport project and other plant budgets have been adjusted, so will we have to adjust or approve to development of these plants and decide which we will favor, the budget or the progress.

Sincerely yours,

EDWARD E. WOLTER, *Manager.*

TENNESSEE VALLEY AUTHORITY,
Knoxville, Tenn., November 13, 1958.

Mr. JAMES T. RAMEY,
Executive Director,
Joint Committee on Atomic Energy,
Washington, D. C.

DEAR MR. RAMEY: This is in further reply to your letter of August 21 requesting comments on the Joint Committee print of August 1958 entitled "Proposed Expanded Civilian Nuclear Reactor Program."

Development of such a statement of objectives is highly desirable, and the present draft covers the most important points.

Before responding to your numbered questions, we would like to comment on other points. The fourth paragraph of the summary on page 1 states that "the design and construction phase would be carried out through an expanded and modified power reactor demonstration program of *privately owned* 'second generation' plants, and through Government construction, by contract with *private industry and non-Federal power organizations*, of advanced experimental prototype plants and of other desirable plants not otherwise proceeding (emphasis added)." We believe that Federal power agencies should be excluded neither

from the ownership of plants in the expanded program nor from any contractual participation in the development of a Government-constructed plant. Participation by all sectors of the Nation's power systems in the development of economical atomic power can be expected to broaden and otherwise benefit the whole program. Therefore it is suggested that the words "privately owned" be replaced with "non-AEC-owned" in the paragraph quoted above and in the section heading on page 10 of the report. As for the second group of words *italicized* above, it is suggested that this be changed to "power systems and private organizations." On page 11, the section heading would then be changed to "B. AEC-Owned Plants."

Speaking for ourselves, TVA needs to keep abreast of technical developments, for it has responsibility for designing, building, and operating powerplants to serve an entire region, with loads that aggregate nearly 10 percent of the Nation's total utility energy requirements; half of TVA's energy output is used by Federal agencies, notably AEC. TVA would like to share in development efforts and has sought to ready itself to do so.

No reference is noted to work on power from fusion. While this is an effort whose probable course is most difficult to appraise, it seems that some reference to it might be desirable. For example, a statement along the following lines might be added at the end of the introduction:

"In making this reevaluation, the possible role of fusion power, while not specifically mentioned, is not ignored. Judging from the present state of development and the magnitude of the problems already foreseeable, it is considered unlikely that fusion power will be a significant factor in civilian power production within the time interval covered by this program statement. However, AEC's research and development work is expected to cover fusion as well as fission power."

The following comments are in response to the correspondingly numbered questions in your letter:

1. Program objectives

We are in agreement with the three major objectives. Definite time and cost goals are important in giving direction to the program, and in providing a means for measuring progress.

With reference to the target dates for the several objectives, it seems doubtful that 2 years is an adequate interval to achieve a cost reduction of one-third to one-half, which we feel is involved in advancing from objective (b) to objective (a); it appears that the earlier date could be advanced, but it may also be necessary to make the second date later.

Objective (a) is of particular interest to TVA. From TVA's point of view "Competitive in cost per kilowatt-hour" would mean competitive with low-cost coal. We will refer to this objective again in our response to your third question.

2. General technical objectives

We are in agreement with these objectives. We would place particular emphasis on the objectives relating to the improvement of fuel elements and the fuel cycle. It appears that substantial progress must be made in this direction before the best selection can be made of future reactor construction projects. We are not unmindful of the importance of making the reactors themselves cheaper and more reliable, but progress in this direction should come more quickly once a satisfactory fuel system has been developed and the materials compatibility problems associated with it have been solved.

We would emphasize the need for developing fuel cycles that are capable of very high conversion of fertile to fissionable materials and, ultimately, of breeding. This development seems very closely related to the problem of lower fuel costs as well as to extending the long range fuel supply. We believe it is generally agreed that only the fast reactor can ultimately utilize more than a small fraction of the natural uranium potential. However, thermal reactors seem to

hold more promise for economic progress for the near future, and for such reactors a strong effort to develop the U–233 thorium cycle would appear to be indicated; we understand that this fuel cycle is regarded as being potentially capable of breeding in both solid and fluid fuel thermal reactors, whereas the recycling of plutonium in thermal reactors does not promise breeding.

3. Technological program

We are glad to see the importance recognized of research, development, engineering, and testing in developing new reactor concepts and making substantial improvements in present ones.

It is suggested that consideration be given to including in the stated program at least one project which would contemplate not building an early reactor of any particular kind but whose objective would be the eventual design of some kind of advanced power reactor intended to be competitive in the lowest cost power areas of the United States. This project as we visualize it would employ a somewhat different approach from that of the reactor demonstration program. The project would begin with analytical and research studies of advanced concepts such as are now associated with hypothetical reactors of the indefinite future and that are being postponed because of more immediate program requirements, would include the development of a low-cost fuel cycle, and, hopefully, would progress ultimately to the design of an economically competitive reactor. There might be a reasonably good chance of achieving this objective within the proposed program period, and such a project should help to provide the positive leadership by the United States Government called for in the Joint Committee print. It is also believed that technical information of broad value to other phases of the program could be expected from the project. We realize that we are suggesting a very difficult project, and one whose success cannot be guaranteed, but the potential benefits are so great that some modest fraction of the national program funds and resources might well be devoted to it. If such a program were reasonably successful it might prove to be one of the better routes toward reasonably early operation of economical reactors. With its emphasis on engineering rather than construction, it would also be a less expensive route than the gradual evolution and refinement of design through several "generations" of plants.

We do not minimize the importance of building plants today that are uneconomic but from which experience can be gained; it is suggested, however, that this additional course should be followed at the same time and should be a recognized part of the total program.

Our final comment in response to your third question is to agree with the objective of more effective interchange of information between the military and civilian programs.

4. Proposed list of reactors

We have no specific suggestions for changes in the table.

5. Estimated costs

No comments.

6. Organization and administration of the program

We agree with the statement of basic policy and the need for positive direction by the AEC.

7. Other types of assistance—domestic nuclear power program

No comments.

We appreciate the opportunity to comment on this proposed program statement.

Sincerely,

HERBERT D. VOGEL, *Chairman of the Board.*

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DEPARTMENT OF THE INTERIOR,
BONNEVILLE POWER ADMINISTRATION,
Portland, Oreg., October 31, 1958.

Mr. JAMES T. RAMEY,
Executive Director, Joint Committee on Atomic Energy,
Washington, D. C.

DEAR MR. RAMEY: The Joint Committee print on proposed expanded civilian nuclear power program enclosed with your letter of August 21, 1958, has been reviewed with respect to our activity, which is marketing Federal power.

Our interest in power production is, in a sense, secondary, since we are not a generating agency; nevertheless, we are interested in power sources which would firm up seasonal power from Federal hydroelectric generating plants, and which could or might be coordinated with the Federal system.

Comments on the specific questions will be made in the order presented in your letter.

1. *Major objectives.*—The three major objectives are reasonable. If the first objective is achieved—competitive nuclear power in cost per kilowatt-hour in the United States by 1970—the nuclear-fired steam plants would be expected to be in operation in the Northwest Power Pool at about that time. The date for added major steam generation, as reported in the United States Corps of Engineers' 308 report, based on our current estimates, is coincidentally within the years of 1968 to 1970. By 1975 to 1980, all available feasible hydroelectric power in the Northwest will probably have been developed. The installed capacity will amount to approximately 25,000 megawatts.

The target year of the second objective—competitive nuclear power in cost per kilowatt-hour in high-cost, free world nations by 1968—undoubtedly falls short of the desires of the high-cost, free world nations, and perhaps underestimates the United States technological capabilities. In view of the goals established by Great Britain (1,000 megawatts by 1962) and the European nations of Euratom (6,000 megawatts by 1965), the year 1965 is recommended as the target year. This would further strengthen the position of the United States in the peaceful applications of atomic energy as stated in the third major objective.

2. *General technical objectives.*—The general technical objectives listed under the 10 broad classifications, if carried out vigorously, will markedly reduce the waiting period for competitive nuclear power.

We consider it to be of greater importance to develop reactor, fuel element, and fuel cycle technology to achieve economically competitive power on a long-range basis than to build in the near term a large number of uneconomical or marginal reactor plants. The United States fossil fuel reserve situation is such that we are well justified in taking this approach. Our major long-range effort, we feel, should be directed toward nuclear fuel breeding to extend our uranium and thorium reserves to the maximum extent possible.

3. *Technological program.*—The technological program appears to be logical and orderly in carrying out the major objectives.

4. *Proposed reactors.*—The 21 reactors listed in table I, not all of which are expected to be constructed, represent essentially all of the present reactor concepts. The pebble-bed reactor, which shows some promise and possibly can be developed into a dual-cycle gas turbine and steam cycle with superheat, can be included in the high-temperature gas-cooled reactor concept.

5. *Cost estimate.*—The Administration has not made a detailed study of nuclear powerplant cost. Others are in a much better position to comment on these figures.

6. *Basic policy.*—The basic policy appears to be proper and reasonable.

Very truly yours,

WM. A. PEARL, *Administrator.*

WOLVERINE ELECTRIC COOPERATIVE,
Big Rapids, Mich., November 6, 1958.

Mr. JAMES T. RAMEY,
Executive Director, Joint Committee on Atomic Energy,
Washington, D. C.

DEAR MR. RAMEY: I have reviewed the print prepared by the staff of the Joint Committee entitled "Proposed Expanded Civilian Nuclear Power Program." I find this print very interesting and I believe your objectives are very well put.

It is my belief that if these ideas are carried forth the program should proceed at a more rapid tempo. However, my personal feelings are that additional work should be done on the smaller prototype reactors to improve the technique and gather data that will be very advantageous to more economical operation of the larger capacity reactors.

Very truly yours,

JOHN N. KEEN, *Manager.*

APPENDIX 5

REPLIES FROM ARCHITECT ENGINEERS

(NOTE.—Page numbers and reference to tables, etc., in the following letters refer to the Joint Committee publication of August 1958, entitled, "Proposed Expanded Civilian Nuclear Power Program.")

ASSOCIATED NUCLEONICS, INC.,
Garden City, N. Y., October 10, 1958.

Mr. JAMES T. RAMEY,
Executive Director, Joint Committee on Atomic Energy,
Congress of the United States, Washington, D. C.

DEAR MR. RAMEY: Following are our comments on the proposed expanded civilian nuclear power program, as requested in your letter of August 21, 1958:

1. Do you agree with the three major objectives (p. 4) of the program? If not, what changes would you recommend?

We agree with the general goal set by the program objectives, but have serious doubts concerning the compatibility of (*a*) and (*b*). Cost reduction becomes more difficult as designs advance and as an industry matures. If it is to take 10 years for nuclear power to become competitive in foreign countries, we believe that it will take more than an additional 2 years for it to become generally competitive in the United States. With reasonable cost for development work, we believe that nuclear power cannot become competitive on a wide scale in the United States before 1973.

2. Are the general technical objectives (p. 5) adequate If not, what additions or deletions would you recommend?

The technical objectives are sufficiently general so that one can hardly argue against any of them. Certainly, all are important to a degree. We believe, however, that there will not be general agreement by the experts as to the relative emphasis which should be placed on these 10 objectives. We suggest that this emphasis be thoroughly discussed in the seminars which you intend to hold on this subject.

3. Please comment on the adequacy of the scope of the technological program (p. 6).

In general, we agree with the scope of the technological program as outlined. In particular, we agree wholeheartedly with your statement that "the ultimate success of the program must lead to strictly commercial plants which are justifiable without financial assistance from the Government." We point out that there are many pitfalls on the road toward this goal. These pitfalls result from the various forms of Government subsidy aimed at stimulating the industry, but which hide the fact that the plants are not really economically competitive. Some of these subsidies, such as 4-percent interest charges on fuel, 4-percent interest charges on D_2O, or complete waiver of use charges on these two materials, fuel life guaranties of 10,000 megawatt-days per ton, and fixed plutonium price supports, are already in effect or are contemplated. Since most of the research and development work in the proposed program will be paid for by the Government, a strong effort should be made to concentrate on reactor designs which have true economic potential and not on those which seem economically attractive because of the effect of some of these subsidies.

4. In your opinion, is the proposed list of reactors in table I the best list for this program? If not, what changes would you recommend?

The proposed list of reactors is a good one provided it does not become frozen. As you pointed out, research and development programs have uncertain endings and plans must be changed accordingly.

5. Do you consider the cost estimates (p. 8) to be reasonable? If not, please point out the areas in which you disagree.

The cost estimate which you present seems to be more than adequate to cover the proposed program.

6. What is your opinion of the policies on organization and administration proposed on page 9? Will they adequately implement the positive leadership required for success of the program?

It is difficult to visualize any other way in which the proposed program can be carried out. During the course of the program, Congress must make certain, however, that the AEC staff does not tie itself too strongly to the scope as outlined but leaves itself open to consider and accept proposals on novel reactor types not specifically written into the program.

7. If it should later prove necessary, what other types and amounts of assistance would you recommend for the domestic program? For the foreign program?

No comment at this time.

On the whole, we think the proposed program is very good. The pitfalls are in the administration and evolution of the program in the light of future research and development rather than in any mistakes in initial emphasis.

We wish to thank you for the opportunity to comment on this proposed program which is so vital to our organization.

Yours truly,

W. E. KELLEY, *President.*

BECHTEL CORP.,
San Francisco, Calif., October 31, 1958.

Mr. JAMES T. RAMEY,
Executive Director, Joint Commitee on Atomic Energy,
Washington, D. C.

DEAR MR. RAMEY: This is in response to your letter of August 21, 1958, requesting comments on the Joint Committee print entitled "Proposed Expanded Civilian Nuclear Power Program" dated August 1958.

Your letter and the accompanying staff document have been reviewed by our organization. We believe that it is essential to have an agreed-on long-range program and feel that the subject document is a very useful step in arriving at such a program.

We agree that the objectives outlined for the program are generally sound and that a framework is provided upon which a logical program can be constructed. We are strongly in favor of a program that will encourage or make possible the maximum participation by industry in planning and executing the overall program.

So far as commenting in detail on the technical questions you have asked, we feel that this can best be considered by the Joint Committee and its advisory panels and staff and by the Atomic Energy Commission, its advisory committees and its technical staff.

We would like to urge full consideration of construction grants for "intermediate generation" power-reactor prototypes as a means of insuring the construction and operation of these plants.

Very truly yours,

J. P. YATES, *Executive Vice President.*

BLAW-KNOX CO.,
Pittsburgh, Pa., October 28, 1958.

Subject: Proposed expanded civilian nuclear reactor program.

JOINT COMMITTEE ON ATOMIC ENERGY,
Congress of the United States, Washington, D. C.

(Attention Mr. James T. Ramey, executive director.)

GENTLEMEN: Responding to your letter dated August 21, 1958, we are pleased to submit the following (paragraphs are numbered to correspond to the questions appearing on pp. 1 and 2 of your letter):

1. We agree with the three major objectives of the program.

2. General technical objectives: Our comments generally agree with the objectives outlined, except as specifically noted below:

(*a*) Cheaper components: To use this as a secondary goal in unproven plants, in favor of early operation, can defer proving of the plants indefinitely. At some point, all considerations must be made secondary to proving the individual components. Only in this way can we learn whether a relaxation of specifications is permissible; that is, by trying a unit with such a relaxed specification.

(*b*) Cheaper field assembly: Minimization of containment and shielding requirements must be carefully considered, as a better definition of these requirements, allowing more concise design and less cost. Minimization which increases hazards to surrounding areas is only foolhardy.

(*c*) No comment.

(*e*) Cheaper reprocessing: It is doubtful whether reprocessing, aqueous, pyrometallurgical or other techniques will significantly reduce reprocessing cost, expressed per unit of uranium recovered. The best approach to this is to simplify fuel element types, and increase fuel element lift. The simpler elements require less complex plants, and the increased fuel life, probably more important, spreads the cost of recovering one unit of uranium over many more units of uranium burned.

It is questionable whether recovery of useful isotopes will reduce costs of reprocessing. The prices charged will reflect as complex a recovery process as the basic uranium recovery, and a fair price will probably only defray the cost of recovery of the isotope, leaving no excess to apply to the uranium.

(*f*) Cheaper waste processing and disposal: At no time can we consider waste disposal as similar to most industrial waste handling, wherein we destroy or change the waste from a noxious form to one that is no longer hazardous, using some chemical or physical means. Radioactive wastes do not allow us such an approach, and we must store them for centuries until they decay. This "perpetual" storage adds a cost which cannot be ignored, since it will be cumulative. This problem is of such magnitude and duration that responsibility is almost forced on the Government rather than on private resources, as the only agency large enough to support this and with an expected life span consistent with the centuries of storage time.

Using isotopes for industrial purposse does not solve this problem, as they must be returned to storage after use, their activity still being far too high to permit unrestricted discard. As to the income from isotopes, comment is made under (*e*) above.

(*g*) No comment.

(*h*) No comment.

(*i*) No comment.

(*j*) Realization of incidental benefits: These areas, particularly radiation chemical processing, have had too little emphasis in demonstration programs. The potential that this new process-variable adds to the tools available to the engineer is tremendous; however, to get more industrial participation, fundamental research and process demonstration must be expanded. This is much like the sales efforts which many companies themselves operate, developing applications and uses for their products to increase product sales.

3. Fuel cycle study: The study of the whole fuel cycle is quite important, as the various parts have been investigated, but we lack the knowledge of how one part really affects another. The study should also include transfer of the fuel cycle from one reactor to another, to see whether the whole cycle, or parts of it, may become standardized for many reactor types.

We are in agreement with other parts of the technological program, and particularly feel that information is its prime object. A kilowatt race is costly, and rarely yields the information really needed.

4. The best list of reactors for study will be known only after they are all built and operated; however, we feel that the range of reactor concepts illustrated offers real potential for feasible powerplants.

5. We feel the estimates are reasonable, in view of the nature of the objectives of the program and the state of knowledge about it. It is well to appreciate now that the costs may be far different from the estimates, as costs on current plants have demonstrated.

6. It is difficult to divorce reactor development from power demonstration programs. It is therefore right that they be under AEC's direction; however, we should consider their being one program, that is, if a reactor, proposed by private sponsors under "power demonstration" has not been completed in "reactor development," we should allow the proposal to be executed. The prototype will be valuable, by whatever name we call the program supporting it.

7. We believe the program of support outlined, for both domestic and foreign powerplants, is adequate for the development of the reactor program as stated. It is impossible to please everyone, and this program is certainly liberal enough to please most people.

GENERAL COMMENTS

Private industry has developed out of needs and desires, which it has met. In all cases, however, it grew only because of a profit motive, where the entrepreneur could realize a gain for his investment. As pointed out in this paper, the United States has an abundance of fossil fuels; therefore, the need for nuclear power is slight, and certainly there is no profit in it now. Industry, however, is not so shortsighted as to neglect the future, as is evident by the large sums of money being spent on research and development activities, which do include nuclear power. The need being slight, and the costs so high, industrial sources cannot be expected to fully support the development program now.

The term "profit motive" is not used here, and should not be construed, as meaning exploitation. It is used to denote the incentive of returns over and above costs, to reward the investor for risking his funds, and to provide more funds to permit future development. If the return covered only costs, expansion would be impossible, and a static situation would result.

In view of the above discussion, with profits not being available in nuclear power as yet, and the Government employing peaceful uses of atomic energy as an element in international relations, it is right that the Government undertake the leadership and financing of a development program. The program as now outlined is a systematic technical approach, and has a liberal means of financing the costs. On the basis fundamentally as outlined, we can expect realistic development of nuclear power within the stated time limits.

Yours very truly,

BLAW-KNOX CO.,
CHEMICAL PLANTS DIVISION,
BRUCE ALEXANDER.

BURNS & ROE, INC.,
New York, N. Y., October 15, 1958.

Mr. JAMES T. RAMEY,
Executive Director, Joint Committee on Atomic Energy,
Congress of the United States, Washington, D. C.

DEAR MR. RAMEY: The Atomic Energy Commission and the Joint Committee on Atomic Energy should be congratulated on the comprehensive and intelligent manner in which the program for the proposed expanded civilian nuclear reactor program has been developed. The program has been well balanced so that the prospects of economic nuclear power by 1970 in the United States may be a reality without the expenditure of large funds for its development. The positive direction and plans as outlined in the program will undoubtedly give an impetus and encouragement to industry to participate more actively in the nuclear effort.

Our comments in regard to the questions that you have raised are answers of detail rather than scope. But we are sure you will appreciate that some of our comments may be necessary for better clarification of the intent of the items discussed in this program. For ease in analyzing the various replies, we are conforming to the questions in the same numerical order that you have used in your August 21 letter.

1. The three major objectives of the program clearly define the intent of the technical development outlined in the following sections. We would like to recommend certain minor changes which would better clarify the objectives and also suggest a minor change in the anticipated dates of nuclear power achieving parity with conventional power.

With regard to the statement that competitive nuclear power will be achieved and demonstrated by 1970 in the United States, it, of course, does not indicate whether this parity will be in high-cost areas or low-cost areas of the country. We are sure it is apparent to you that conventional power in this country varies from 3 mills per kilowatt-hour to as high as 15 mills per kilowatt-hour in certain locations. The average might be considered to be around 7 to 8 mills per kilowatt-hour. We would think that the intent of achieving parity in 1970 would be with the average cost of conventional power at that time. The same logic applies to the free-world nations, which probably have a greater range in power costs and, on the average, is higher than that of the United States. We believe the 1968 European date is too close to the 1970 date for the United States, since the higher cost of power in Europe is expected to generate considerably more activity in nuclear-plant application. It is our feeling that a target date of 1965 would be more

realistic for demonstrating and achieving nuclear-power costs that will be competitive with the average conventional cost in Europe.

Comparison of conventional-power costs with those of nuclear-power costs based on experience with nuclear projects preceding the 1965–70 date will not clearly prove such parity. In conventional projects, we consider the life of such plants to be between 25 and 35 years, and such figures are based on proven experience through many years of conventional powerplant operation. One can only assume that nuclear plants will have such a life by 1970, because, in fact, we have no experience to confirm that this is true. Therefore, even though capital costs and fuel costs may make it appear that there is a competitive condition, it would, in fact, not be final proof until such a nuclear plant has demonstrated that it has an operating life comparable to that of a conventional plant. The same factor must also be taken into account when comparing the maintenance cost of a conventional and nuclear plant. One can only assume what maintenance costs will be during the short period when, in fact, it may be less or greater. However, our point is that many more years of operating experience will be necessary before such parity could be demonstrated, based on records rather than assumptions.

2. The general technical objectives enumerated on page 5 point up clearly those areas which will require improvement if the major objectives are to be achieved. One cannot take issue with the need for cheaper components in nuclear plants. The high cost of the major equipment has indeed made it difficult to achieve economic nuclear power. Standardization, particularly by our technical associations, will ge a long way in reducing the cost of such equipment. As we gain more experience in the operation of reactors, we are sure further reductions will be achieved in eliminating some of the overdesigns necessary, due to the uncertainties of reactor safety. A great deal of duplication and backup safety has been put into our present reactors, due, of course, to lack of experience. Both improved standardization and experience will produce these cheaper components. However, we must be on guard not to reduce the cost of components to the point where the safety of the plant is affected or where the maintenance costs will be appreciably increased. Again, experience will permit a balance so that all factors are given their proper value.

There are many areas that we are familiar with where cheaper materials might be used, but, because of uncertainty, it has been necessary to go to the more exotic types. A greater effort should be made in adapting the carbon steel, aluminum, copper materials for application to the nuclear plant.

In this section, as well as some subsequent sections, there is a particular emphasis on producing better fuel elements at a lower cost. Although it may be understood, there is no clear statement that the homogeneous reactor types should be actively developed in light of the fact that fuel costs can, we believe, be appreciably reduced by this technology. Some of the research and development funds that are earmarked for fuel-element development and reprocessing may be more productive if spent on solving some of the corrosion and mass-transfer problems of the homogeneous reactors. The initial problems in these types should not discourage their further development in light of the need for lower fuel costs.

Reference has also been made in this section to higher steam temperatures in order to improve the power-generation efficiency of the nuclear plants. Actually, in certain nuclear designs, such as the heavy-water and graphite-moderated types fueled with natural uranium, the fuel costs are generally small in comparison to the construction costs of these plants. Improved efficiency would thereby give small gains in fuel costs, but not so much in overall costs unless capital costs can also be reduced. In order to obtain both higher efficiency and lower capital costs, efforts must be made to build a plant to utilize existing technology on high pressures and high temperatures for steam plants and, at the same time, to so design the equipment that the total cost will not be prohibitive. In this manner it may be possible to get an atomic plant with steam as a prime mover which is compeitive.

For the same reason, higher temperatures, if considered, should also be directed toward gas-turbine application where the savings and capital cost could be significant. We are, therefore, suggesting that one of the technical objectives would be in developing economic nuclear power utilizing gas-turbine generation.

3. The technological program as outlined on pages 6, 7, and 8 is very complete in its definition and scope and leaves very little that requires further definition or amplification. Again, we want to reemphasize the need for directing some of this development to the homogeneous types which are not defined in the text of the proposed program although they are listed in the appendix.

4. The proposed list of reactors in table 1 gives a natural continuation to the prototypes presently being developed and which appear to have prospects for achieving economic nuclear power. There are a number of other reactor types which suggest themselves as being attractive and will require little additional development work in order to demonstrate their feasibility and economics. As you may know, the Russians have successfully demonstrated boiling and nuclear superheat in their graphite-moderated, water-cooled reactors. Pressure-vessel sizes of the boiling-water type are reaching their upper limit in the 12- to 15-foot diameters, thereby limiting the power-generating output. Pressure-tube designs of the graphite-moderated type can be built in appreciably larger sizes, and it would seem reasonable to investigate and develop, if feasible, boiling and nuclear superheat in the pressure-tube types.

We have investigated other advanced reactor designs which appear attractive and should be considered in light of this program. There is a great deal of merit in using gas cooling, both in the bismuth uranium and in the fused-salt types. The mass-transfer problems and corrosion problems of circulating fused salts and liquid metals have been severe. By considering static high-temperature liquid metals and fused salts and using gas as an internal coolant, it is possible to still achieve high efficiencies at low fuel inventory and reduce problems in metallurgy. We have also been investigating the possibility of a uranium hexafluoride gas reactor on which little or no research work has apparently been carried out by American laboratories. This particular type was described in a recent article in the August issue of Nucleonics. This entirely different concept is attractive, particularly from the fuel-cycle point of view. However, there is a great deal of metallurgical investigation that will be necessary to improve its feasibility. We were interested to learn that the Russians announced their interest in this type at the recent Geneva Conference.

5. We are sure you appreciate the difficulty of estimating nuclear powerplants, as the history to date on some of the constructed projects has been poor. The second-generation, large-size nuclear projects that are to be constructed at present-day costs, to the best of our experience, will cost approximately $350 per kilowatt. Smaller plants and the intermediate sizes will, of course, be greater on a per-kilowatt basis. Since many of the proposed projects are to be constructed and in operation in the latter half of 1960, one should take into account the cost of construction during this period. Present records show that costs are increasing at an average of 6 percent per year, so one might expect, if present trends continue, that present-day costs of second-generation plants when projected to the late 1960's would, in fact, be increased by 50 percent by that time, so that large-size plants will cost between $450 and $500 per kilowatt. However, for the average of all the sizes, the $500-per-kilowatt figure is probably low. The extent of its difference from the overall average, of course, depends on the proportion of large- and small-size plants actually being built. We would anticipate that a figure of $600–$650 per kilowatt might present a better overall average for this period.

It is, of course, difficult to give an estimate on design and development costs without defining in better detail the extent of these projects and the areas that will be made during this period, based on past records. The estimated figure of $375 million for a construction effort of over $500 million would, to us, appear reasonable.

6. The policies on organization and administration proposed on page 9 are sensible. The suggested methods are a natural continuation of present policies and permit all parties to show their interest and exert their leadership in this program.

7. The domestic and foreign program, as enumerated on pages 10, 11, and 12, also appear reasonable to us, in light of past experiences in the nuclear-power program. We believe some thought should be given to the period beyond 1970 so that there is a continuation of the civilian power program after this period. Although 1970 is an important date to plan and work toward, it should not create a vacuum that would prohibit continued and orderly development following 1970 based on the experiences previous to this time.

We believe, also, that, in addition to some of the assistance suggested on page 10, special training on the part of the Commission for operation of power reactors should be included. A school or training program organized by the Com-

mission to aid the utilities in preparing themselves for the nuclear program would be a worthy contribution. Although there are methods for our utilities to enable their operators to receive training, there is not, to our knowledge, a school where these operators can go for just that training which will make them suitable for the nuclear-power age.

In our offer to assist projects in other countries, it is necessary, as enumerated on pages 11 and 12, to insure the availability of technology as well as enriched fuel. There is always a question as to the extent that our technology can be made available to other countries without infringing on the proprietary knowledge of a company. The danger is not so much in releasing proprietary information that might create a competitive situation in a foreign country, but, rather, the use of this information by foreign companies not adequately knowledgeable to translate this information successfully. The risks of having inexperienced manufacturers duplicate techniques developed in this country in connection with nuclear projects are too great to just freely make it available without properly checking on the abilities of such organizations to duplicate this work. The licensing arrangements presently being practiced by the American manufacturers and their counterparts in other countries is a reasonable approach and insures a good translation of our technological development. Other approaches would have to be evaluated before our information is freely disseminated.

We believe the offer to supply enriched uranium is very important to the success of our nuclear development in this country. The method of assuring this supply is also important. The foreign countries would have more confidence in continuity of supply if it did not depend primarily on the United States. Some international agency, such as United Nations or the IAEA, should be the source for this fuel rather than that of the United States.

Generally, American engineers have been selected for the design of plants that are financed by the Export-Import Bank. This procedure has proven to be very satisfactory because of the depth of experience available with the United States engineering organizations. Nuclear-power projects to date have not followed this traditional approach primarily because the manufacturing companies were initiated early in the development programs and they have attempted to hold this primary position with engineering subcontracted to the architect-engineers. This procedure has not been too satisfactory in this country. Every effort should be made to encourage the selection of experienced architect-engineers in the United States for the design of these power stations so that their knowledge in costs and design will insure the success of these foreign projects.

We hope our replies will be helpful to the Joint Committee in finalizing this very important program. Your committee should be congratulated on the excellent document describing the proposed expanded civilian nuclear-power program. A great deal of thought and imaginative planning is clearly demonstrated and insures that this country will maintain its leadership in this very important field.

Very truly yours,

R. C. ROE, *President.*

CATALYTIC CONSTRUCTION CO.,
Philadelphia, Pa., October 22, 1958.

Mr. JAMES T. RAMEY,
Executive Director, Joint Committee on Atomic Energy,
Congress of the United States, Washington, D. C.

DEAR MR. RAMEY: We appreciate the invitation contained in your letter of August 21 to comment on the proposed expanded civilian nuclear reactor program.

It is clear that a great deal of expert thought and effort has gone into the preparation of this proposed program. We certainly concur generally with it in its present form and have no suggestions at this time for additions and modifications.

We wish you every success in carrying out this program because we believe it is among the most vital of United States Government activities.

Very truly yours,

T. ELLWOOD WEBSTER, *President.*

COMMONWEALTH ASSOCIATES, INC.,
Jackson, Mich., October 31, 1958.

Mr. JAMES T. RAMEY,
Executive Director, Joint Committee on Atomic Energy,
Congress of the United States, Washington, D. C.

DEAR MR. RAMEY: We wish to thank you for your letter of August 21, 1958, and the opportunity to comment on the proposed expanded civilian nuclear power program which is outlined in the Joint Committee print of August 1958.

Our comments are rather brief and are in answer to the questions included in your letter.

1. Do you agree with the three major objectives (p. 4) of the program? If not, what changes would you recommend?

We are in agreement with the major program objectives which are to achieve competitive nuclear power in the United States within 10 years and on certain foreign locations in 8 years.

2. Are the general technical objectives (p. 5) adequate? If not, what additions or deletions would you recommend?

The general technical objectives seem appropriate for achieving (1) lower capital costs and (2) lower operating costs. Under Item (a): Cheaper Components, reference is made to a number of possibilities which could result in lower investment costs, although these only become evident in plants whose technology is well understood and detailed design is in progress. Only as engineering and construction experience is obtained will it be possible to devise mechanical and electrical systems of less complexity which can utilize more items of commercial availability.

Perhaps one of the most rewarding studies of cost reduction might come from the total elimination of certain functional items which, even though considered desirable, may not be vital for operational and safety reasons. It is true that it is impractical to evaluate some of these factors before first generation plants are in operation but, in the decade covered by the proposed program, it would seem that a place should be given for their study and evaluation. It is possible that certain functional items might be eliminated in some instances by utilizing services more economically available at other locations or obtained by joint efforts with others. Some items which perform their functions in series or in parallel with others should be constantly examined on the basis of operating experience to determine if they are actually necessary. Constant association with the design of reactor plants for this program should reveal any such cost reduction possibilities.

4. In your opinion, is the proposed list of reactors in table I the best list for this program? If not, what changes would you recommend?

We hesitate to comment on the list of some 20 types of power reactors proposed for development during the next decade but it would appear that a sufficiently wide variety of types is included. However, we believe that some of these types may be eliminated early in the program and that others not now being considered could prove to be of great interest. We suggest that the list maintain a maximum flexibility of reactor types.

5. Do you consider the cost estimates (p. 8) to be reasonable? If not, please point out the areas in which you disagree.

The estimated costs appear to be reasonable considering the wide range of sizes and that these are complete plants including electric generating facilities.

6. What is your opinion of the policies on organization and administration proposed on page 9? Will they adequately implement the positive leadership required for success of the program?

In connection with the administration of the program, provision is made for AEC to design and construct reactors when satisfactory proposals are not received in a specified time. In this connection it might be pointed out that lack of proposals could result from the belief that the type of reactor is not a promising one. If this possibility existed, it might be wrong to require AEC to proceed with mandatory construction of the reactor.

Yours very truly,

E. V. SAYLES, *Vice President.*

EBASCO SERVICES, INC.,
New York, N. Y., November 17, 1958.

Mr. JAMES T. RAMEY,
Executive Director of Staff, Joint Committee on Atomic Energy, Congress of the United States, Washington, D. C.

DEAR MR. RAMEY: Before commenting on the proposed expended civilian nuclear reactor program, dated August 1958, we would first like to discuss certain principles which we feel should be basic to any such program.

1. We believe that two distinct objectives can be identified for the AEC civilian nuclear reactor program. The first, or short-term objective, is an early demonstration of competitive nuclear power or a clear determination of the circumstances under which nuclear power would be competitive. The second, or long-term objective, is the continuing development of advanced nuclear technology on a broad basis so that the designers of future plants may take advantage of the most recent developments. It is important not to confuse these objectives. Each program activity should be classified according to which of these objectives it is intended to advance.

2. The AEC program should be based on the assumption that industry will build and operate nuclear plants when they become competitive. There is no intention here to differentiate public, private, and cooperative utilities. All may be considered part of the utility industry with relatively similar incentives.

3. The electric power industry has goals indentical with those of AEC. Equipment manufacturers, engineer-constructors, and operating utilities are all anxious to build and operate plants leading toward competitive nuclear power.

4. We believe strongly that full-scale or prototype plants should be built and operated by industry—not by AEC. Only in this way can full advantage be taken of normal business incentives so necessary for maximum progress toward early demonstration of competitive nuclear power.

5. We believe that AEC should provide the climate under which industry will find it possible to build prototype and large-scale demonstration plants during the period when nuclear power is not economic. Providing such a climate may require significant changes in AEC policy and probably a revision of sections 44 and 169 of the Atomic Energy Act.

6. We believe that construction of power reactors by AEC should be limited to reactor experiments to test the technical feasibility of novel concepts. These should be no larger than necessary to provide essential technical data. Generating facilities should not be provided, unless the omission of such facilities would compromise the value of the technical data.

7. We believe that competitive nuclear power will be reached soonest if effort is concentrated on the most promising reactor concepts. We believe that sufficient experience has been accumulated in the programs of the AEC and of industry to permit a judicious selection of a small number of concepts for concentrated effort.

8. We believe that major reductions in capital costs will come from the construction of successive models of the same reactor types taking advantage of experience gained in the construction and operation of previous models. Ideally this implies that time will be made available for the analysis of the performance of each model and also that full use wil be made of the experience and talent of the same development and design teams on successive projects.

9. Progress cannot be measured by the number of nuclear kilowatts produced or the number of reactors operated or even the variety of concepts that are pushed to full-scale construction. The overriding consideration is whether the program represents the best effort in the direction of economic nuclear power.

With these principles in mind, we offer the following comments on the questions raised in your letter.

Do you agree with the three major objectives of the program? If not, what changes would you recommend?

Although we feel that the dates mentioned in objectives (*a*) and (*b*) on page 4 of the Joint Committee report are necessarily somewhat arbitrary and are not really essential to express a determined effort to achieve competitive nuclear power at the earliest reasonable date, we have no strong objection to the wording inasmuch as a reasonable program to achieve these objectives should be

essentially the same whether the dates are mentioned or not. We would hope, however, that the program followed is one planned for a direct approach to the goal rather than an exploration of every byway.

The danger in fixing rather rigid dates lies in the temptation to accelerate the more speculative reactor types in the hope that one might come through on a "long shot" gamble if the most promising types appear to be missing the goal by a few mills per kilowatt-hour or by a few years.

We also question the short-time interval between the target dates for competitive nuclear power abroad and in the United States. Two years is somewhat less than one generation measured in terms of the normal gestation period from conception to completion of a nuclear powerplant. Although the bare phrase "competitive in cost per kilowatt-hour" is rather vague, it seems optimistic to expect that a reduction as large as the substantial difference between the high cost of electricity in some foreign areas and that in even the highest fuel cost areas of the United States can be achieved in so short a span of time. We agree that the main target should be the achievement of competitive nuclear power in the United States.

Are the general technical objectives adequate? If not, what additions or deletions would you recommend?

In our opinion the 10 technical objectives listed do not represent definable goals but rather are areas of investigation which seem to be worth exploring. They are not directly related to the three "program objectives" on page 4 of the report. Five of the ten list the principal cost components of nuclear power generation which must be reduced in order to achieve competitive nuclear power. "Cheaper components" and "cheaper field assembly" define areas in which substantial cost reductions can be expected if successive models of a given plant type are built making use of past experiences and cost conscious design. So far as achieving competitive nuclear power is concerned improvement in fuel cycle costs are most likely to result from gradual evolution based on current fuel element concepts rather than from dramatic innovations. For example, water-cooled reactors will most probably use fuel elements of uranium dioxide clad in zircaloy. Certainly, the short-term program should include concentrated effort on a reduction of the cost of such elements. Means of increasing the thermal conductivity of the oxide are worth while (the principal gain would be a reduction in fuel inventory), but the most fruitful improvements will come from a reduction of the fabrication costs and in insuring of long fuel life. The former will certainly benefit by increasing the production volume for identical elements and perhaps also by mechanization and automation techniques. Attaining long fuel life may be a mere matter of testing under actual operating conditions and quality control. There seems to be no short cut to this process. A considerable amount of development work on alternate fuel element materials and designs may also be undertaken but for the most part this should be classified as long-term development.

For the short term, cheaper reprocessing may or may not require the development of new methods such as pyroprocessing techniques. The principal problem in chemical processing is the high cost resulting from the relatively small magnitude of the processing load compared with normal chemical operations. Certainly alternate methods should be explored but caution should be exercised in initiating large-scale plant construction unless real economic advantage can be shown. Waste processing and disposal is another area in which continual development is desirable.

The other five objectives indicate areas which are worth exploring but for the most part are "long-term developments" which are unlikely to contribute to the earliest demonstration of competitive nuclear power. Higher temperature steam, per se, is important only if it leads to cheaper power. In particular, nuclear superheat for water-cooled reactors is worth exploring and probably worth investigating in a reactor experiment but because of high initial capital costs may not be economic for the short term. On the other hand the combination of nuclear steam and fossil fuel superheat has proved advantageous in several projects and may well be useful in reducing excessive development cost burden and perhaps mght even find commercial application.

The use of plutonium as fuel and the attainment of breeding probably are not essential to the short-term goal of early demonstration of competitive nuclear power. They should be explored as part of the long-term program. The use of natural uranium does not appear to be essential to the short-term goal and probably has even less promise in the long term. On the other hand metallic uranium, which might be somewhat enriched, may prove useful in the organic

moderated reactor if tolerable control of dimensional instability can be achieved by alloying, heat treatment, or reactor design.

The area identified as "Incidental benefits" should be investigated, at least as a long-term development, but it is unlikely that such byproduct applications will have any significant effect on the short-term goal of early demonstration of competitive nuclear power.

Other areas of investigation should probably be mentioned as, for instance, the field of nuclear safety with emphasis on the study of kinetic behavior, the sudden release of nuclear or chemical energy, and minimum-cost containment. Also, certain areas suggested by the list of possible power reactors in table I do not seem to be covered in the list of technical objectives; examples are the several fluid fuel concepts, process heat or other industrial applications, and epithermal or undermoderated concepts which have several interesting and potentially useful applications.

Please comment on the adequacy of the scope of the technological program.

We agree with the general pattern of development from basic research and development through construction of experimental and demonstration reactors but we believe firmly that industry should participate, as a responsible partner, in the construction and operation of every prototype or full-scale plant. The advantages of this approach are threefold:

1. The Government will spend less money relative to the progress made.
2. Progress toward economic nuclear power will be accelerated to the extent that normal commercial incentives can be applied.
3. Industry will benefit both from obtaining maximum operating experience and from earlier attainment of the date when nuclear plants can be built on an economic basis.

We believe that the technological program should recognize the distinction between the short-term objective of early achievement of competitive nuclear power and the long-term objective of broadening the base of nuclear technology to enable further advances in the economic use of nuclear energy. The short-term goal must have priority. Construction of prototype and full-scale plants of the most promising types is essential even though the incremental reductions in cost can be expected to diminish as competitive status is approached.

The various activities of the long-term program should be subjected to careful analysis of potential benefits and an orderly progression through successive stages of development and experimental investigation making fullest use of past experience. This does not mean that we do not favor a vigorous program aimed at the long-term objectives nor that the construction of reactors or even powerplants to test various novel concepts is inappropriate but we believe in the principle that construction of prototype or full-scale plants should be undertaken with industry participating in both construction and operation. If a prototype is worth building at all it is worth the benefit of industry participation. In the event that risks and uncertainties are too great to permit industry participation, the AEC may wish to proceed with a reactor experiment designed solely to test the technical feasibility of certain concepts.

We agree that improvement of the fuel cycle should be an essential part of the technological program. A distinction should be made between short-term and long-term goals. Intensive work in both areas is needed but the former should be given priority. The short-term program should emphasize large-scale testing in operating power reactors to assure statistical reliability, the experimental testing of alternate fuel elements both in test reactors and operating power reactors, and the standardization and mechanization of manufacturing procedures. These phases of the program involve both reactor operators and fuel fabricators and suggest undertaking cooperative programs with AEC support. The short-term program is not likely to benefit from the construction of additional test reactor facilities beyond those currently planned but it may be necessary to assign priorities. The long-term program can tolerate delays. Additional facilities for post-irradiation examination will probably be required. The advisability of providing these at power reactor sites should be examined and AEC should be authorized to support such facilities if desirable.

In your opinion, is the proposed list of reactors in table I the best list for this program? If not, what changes would you recommend?

We believe that selection of reactor types for construction should be made in accordance with the short-term and long-term objectives. We believe that most rapid progress toward the short-term goal will be achieved by selecting not more than three reactor types which are most likely to reach competitive status at the earliest date and to concentrate on effecting reductions in construction and

operating costs by further development and the construction and operation of successive models. Our own evaluations and experience point toward three that can be singled out as candidates but we suggest that full advantages be taken of the design studies now being initiated with AEC sponsorship under the 1959 AEC Authorization Act for a critical selection of the most promising candidates. Not only should the selected types be pushed toward competitive status but they should serve as yardsticks to compare the relative promise of other concepts. Other concepts should be followed, as appropriate, in the long-term program with the view of expanding the technological base. In general, construction of prototype plants with these alternative types should be undertaken only if careful evaluation indicates a definite advantage over the selected yardstick concepts. Obviously, the whole program must be subjected to continual review to assure that the overall goals are being met.

We intend no criticism of reactor plant projects now scheduled for construction and believe that their construction should be completed even though they might not meet the criteria we have set up. We recognize that the projects were initiated at a time when the relative economics were ill defined. In every case, useful information will be developed and in fact the selection of the most promising types should take into account lessons learned from these projects. As discussed elsewhere, we have no objection to the construction of reactor experiments if needed to determine technical feasibility of novel concepts, nor, for that matter, to the construction of prototype plants if carried out with the participation of industry and wihout interference with the attainment of the short-term goal.

We believe that table I includes the major reactor types to be given consideration. In line with the above discussion, we would not hazard a guess as to how many of these should actually be constructed by 1970, nor do we feel that the suggested scheduling or sequence or the electrical rating should be given any firm significance.

Do you consider the cost estimates to be reasonable? If not, please point out the areas in which you disagree.

We believe that, in general, expenditures at the indicated level should be ample to provide a vigorous program. The average cost per kilowatt should be well below the estimate of $500 per kilowatt if emphasis is placed on plant types most likely to become competitive at an early date. Our major concern is that of how the money should be spent. We urge that whatever national resources are dedicated to the achievement of economic nuclear power be spent wisely. We believe that it would be more in the national interest to spend design, construction, and operation dollars on a few reactor systems than on many. We believe that research and development efforts should be directed carefully toward the solution of the critical problems relating to these few systems. We urge that initiation of new projects involving major commitments be preceded by careful analysis to assure that they will contribute to the overall goal of economic power. At the same time projects underway should also be scrutinized periodically to be sure that they continue to show promise.

In the interest of placing the contemplated expenditures in better perspective it is noted that the suggested average rate of $125 to $150 million per year for the base program of general reactor research and development, exclusive of laboratory facilities, would be sufficient to provide about 1 million kilowatts of new conventional plants capacity each year. The total addition rate for all electrical generating capacity in the United States is of the order of 10 million kilowatts per year. It is further noted that the anticipated design and development cost for the expanded program is estimated as $375 million and the estimate of $500 million for construction of 1 million electrical kilowatts represents sustantially more than $300 million excess in plant investment over the cost of installing a similar capacity in conventional plants. Thus, net cost of the nuclear development program over the next 5 to 7 years as estimated on pages 8 and 9 is equivalent to fully 15 to 20 percent of the value of new generating plants anticipated in the same period of time. Obviously such relatively high development costs can never be recovered if nuclear power merely meets the competition of conventional plants. Substantial reductions in energy costs must be anticipated in order to justify such an expenditure on economic grounds.

What is your opinion of the policies on organization and administration proposed on page 9? Will they adequately implement the positive leadership required for success of the program?

We agree that the AEC should provide positive leadership to make certain that program objectives are achieved. We believe, however, the fullest possible

participation by industry is essential to assure the achievement of the program objectives in terms of practical results. In particular, we feel strongly that industry should participate in the construction and operation of any prototype or full scale nuclear plant. Unfortunately present AEC policies and provisions of the current Atomic Energy Act severely hamper effective participation by the utility industry. Specifically, there has been no sound basis for a truly cooperative project between AEC and industry aimed at meeting the common goal of both parties. Present AEC policies based on existing legislation make it particularly difficult for private electric utilities to participate in desirable projects. Unless a utility or a utility group can see its way clear to assume the full burden of building and operating an uneconomic plant it is virtually excluded from participation. At the same time AEC is not barred from undertaking the same project completely at Government expense. The ground rules established by AEC for its power demonstration program are an attempt to get around the difficulty. The modifications proposed still do not overcome the basic problem.

If the Government will provide the minimum incentives which make it possible to participate in a sound, businesslike, truly cooperative manner, United States industry including equipment manufacturers, engineer-constructors, and operating utilities will respond with enthusiasm. Under such a climate there would be no question of industry support of any worthwhile project.

We object to the establishment of deadlines for the initiation of a project other than a cutoff date for submission of competitive proposals. In inviting proposals, industry should be given sufficient time to prepare sound propositions.

In general, we do not like to see an obligation to proceed with construction if the project is highly speculative. We note with approval that "the nuclear powerplants designated should be based upon reasonably well demonstrated technology." If this principle is followed there should be little reason to abandon a construction project. However, many of the reactors suggested in table I do not now meet that criterion. We would hope that in such cases development work supported by AEC, industry or by AEC and industry jointly could be undertaken without an obligation for construction until a more realistic appraisal could be made.

We believe it is appropriate for AEC to invite proposals for designated projects if full cognizance is given to the opinions of industry and utility people. At the same time, AEC should be given freedom to consider unsolicited proposals on their merits and to support those which will clearly make a worthwhile contribution toward the fundamental goal.

The types of assistance, in addition to research and development assistance, which AEC currently offers on cooperative programs may distort the economic picture. For instance, waiver of use charge, or an abnormally low use charge which does not represent full cost recovery, opens the door for a continuing subsidy which may be difficult to terminate. Furthermore, it tends to reduce the incentive to minimize fuel inventory and may lead to improper optimization of the reactor design. Similarly, the loan of heavy water without charge, or at an abnormally low charge which is not representative of the cost of using heavy water on a commercial basis (and may not even represent full cost recovery to AEC based on present production costs), certainly distorts the economics of heavy water reactors. Purchase of plutonium or U–233 by AEC at an artificially high price is a form of subsidy which will be difficult to terminate. On the other hand, agreement by AEC to purchase plutonium at a fuel grade price, representing the true value of such material to a potential commercial user, is in no sense a subsidy and is quite proper. Agreement by AEC to accept spent fuel elements with the imposition of a processing charge representing the probable commercial cost of such services when such services are commercially feasible is also appropriate, but charging an abnormally low rate would tend to distort the economics of a nuclear plant. In this connection, it does not matter whether the material is actually processed. In fact, it may well be advantageous for the AEC to store spent fuel elements without processing until a sufficient backlog has been accumulated to warrant the construction of a commercial processing plant of reasonable capacity.

On the other hand, the type of assistance which would preserve the incentives of the operating utility to reduce generating costs and at the same time overcome the major stumbling block of a prohibitive financial penalty in undertaking a nuclear plant project, namely a sharing of the excess construction costs, is not permissible under current or proposed ground rules. In particular, we believe that those projects are most worthy of support which are closest to reaching competitive status. These require virtually no research and development effort

and the minimum amount of financial assistance. They should be given every encouragement.

We would prefer not to have present formulas as to the type of Government assistance to be provided. We would rather see the proposer given flexibility as to the type of assistance desired and, ideally, have financial support related to the activities where deficiencies actually occur in programs aimed at accomplishment of the objectives of economical nuclear power.

Closing the final gap to competitive nuclear power will require the full weight of experienced design and talent. Although a certain amount of competition is desirable we do not believe that impartiality in sponsorship of projects should be carried to the point of discriminating against experience.

> If it should later prove necessary, what other types and amounts of assistance would you recommend for the domestic program? For the foreign program?

As we pointed out in commenting on your sixth question, we do not believe that the present types of assistance provide adequate incentives for the kind of cooperative program between AEC and industry which is necessary if the overall goals are to be met.

We urge that immediate consideration be given to some plan which does not discriminate against investor owned utilities. Such a plan should provide financial assistance to pay at least a portion of the excess cost of building and operating a nuclear powerplant over the costs for a conventional plant. In granting such financial assistance the AEC should not require the sponsors to relinquish management control over the construction and operation of the entire plant. The Shippingport-type arrangement in which the Government retains title to the reactor and/or other essential parts of a nuclear plant restricts the application of normal business practices and incentives in minimizing costs. If a nuclear plant is based on well demonstrated technology and of a type showing reasonable promise of becoming competitive, the necessary Government contribution should be a minor fraction and the operating utility should have equity in the entire plant.

For the foreign program, we cannot suggest other types of assistance beyond those listed on pages 11 and 12 of the report. We consider a solution to the problem of third-party "liability" of immediate and major importance if plants of United States manufacture or design are to be built abroad.

As in the domestic program, we do not consider it prudent to provide hidden subsidies in the form of artificially attractive prices for nuclear fuel materials and services. If Government warranties are considered on fuel element performance or fabrication price, or price for other services, as is provided for in the Euratom agreement, we believe that such warranties should be reasonably consistent with United States industry's ability to make and meet such warranties and prices.

We hope that our comments will prove helpful to the Joint Committee in formulating a sound program for the development of economically competitive nuclear power.

Very truly yours,

LEONARD F. C. REICHLE,
Nuclear Engineering Director.

THE FLUOR CORP., LTD.,
Los Angeles, Calif., October 22, 1958.

Mr. JAMES T. RAMEY,
Executive Director, Joint Committee on Atomic Energy,
Congress of the United States, Washington, D. C.

DEAR MR. RAMEY: This is in reply to your letter of August 21, 1958, requesting comments on the publication Proposed Expanded Civilian Nuclear Power Program, dated August 1958. The following numbers correspond to the paragraphs in your above letter:

1. Program objective

I am not sure that I understand the significance of the year 1970. It is my opinion that nuclear power will be competitive in certain areas of the United States prior to 1970, and in other areas it will not be competitive until considerably after 1970.

I am not familiar with the cost of power in other free-world nations, so I cannot comment on the competitive cost there by 1968.

I question the statement that we occupy a position of leadership in the eyes of the world in the peaceful applications of atomic energy for power. Great Britain has presently under construction or operating approximately 1½ million kilowatts, which is considerably more than we have here in the United States. I think the world leadership should be either eliminated or qualified.

Late last year I visited the Calder Hall atomic powerplant and talked to various people participating in the British program. They are quite outspoken in the fact that they have taken over the leadership in the development of atomic power and have no thoughts of relinquishing it. We are associated with one of the companies participating in the design and erection of the Bradwell station. This is a 300-megawatt plant, costing $336 per kilowatt (exclusive of fuel), with steam conditions of 770 pounds per square inch absolute and 704° F.

2. Technical objective

I question the necessity of paragraph (b), "Cheaper field assembly." The items enumerated are all being done by the major construction organizations in this country. For a number of years the cost of labor as measured in dollars per hour has been increasing faster than the productivity of labor. This has resulted in a higher cost field assembly in each succeeding year, and I see no indication that this trend will change. The mechanization of these operations has reached a point where there is very little room for improvement. The minimum shielding and containment features are determined by the health and safety requirements of each installation. It is my opinion that the minimum requirements are being incorporated into present designs, and perhaps these can later be reduced consistent with the new-design criteria.

3. Technological program

It appears there should be greater opportunities to reduce overall costs by lowered fuel-cycle costs than by reducing capital costs. Also, special emphasis should be placed on higher temperatures and higher pressures for the steam cycle approaching those of modern steam-electric power installations.

4. Proposed list of reactors in table I

It is my opinion that this subject has been given a very thorough study, and I do not feel that I am qualified to question any of those selected.

5. Estimated cost

I assume these figures represent an approximate estimate of cost for this program, and I do not have any information which would allow me to question them.

6. Administration of program

I believe the lowest cost for the power demonstration program could be achieved by working exclusively with the privately owned utilities and at the same time not impose any financial penalties on them. This could be accomplished by the Government underwriting the differential capital cost between the nuclear and conventional powerplant and also underwriting the additional operating cost. The plant could be amortized over a definite period of time, say 10 years; and at the end of this period the utility could either continue to operate it as is, modernize it as deemed advisable, or dismantle it. At this time the plant would become the property of the utility, and the Government would have no further obligation except the supply of fuel if not then available from other sources.

The American people are going to pay for this program in the form of increased taxes, increased cost of electrical energy, or reduced dividends to the shareholders of the participating companies. Since we all stand to gain from the results, I think we should all participate in the cost. This policy would eliminate the resistance to the present program due to the financial penalties involved.

7. Other types of assistance

This would not be required in the domestic program if the policies outlined in paragraph 6 were adopted. In the foreign program I think the assistance outlined is sufficient.

Sincerely yours,

D. W. DARNELL,
Chairman of the Board.

32855—58——11

GIBBS & HILL, INC.,
New York, N. Y., October 24, 1958.

CONGRESS OF THE UNITED STATES, JOINT COMMITTEE ON ATOMIC ENERGY,
Washington, D. C.
(Attention: Mr. James T. Ramey, Executive Director.)

GENTLEMEN: It is a pleasure to respond to your letter of August 21, 1958, requesting our views and comments on proposed expanded civilian nuclear reactor program.

By way of background, Gibbs & Hill has been identified with the work of the Atomic Energy Commission on a contract or subcontract basis almost continuously since 1950. Facilities for the Savannah River project, the Idaho Falls operations office, the proton accelerator at Princeton, and the S3G submarine prototype at Schenectady are typical. Our continuing interest in the nuclear field is exemplified by engineering services currently being rendered to Westinghouse for the 11,500-kilowatt reactor powerplant in Belgium, and to Edisonvolta for the 160,000-kilowatt Enrico Fermi reactor powerplant in Italy.

As designers of central generating stations, Gibbs & Hill is naturally interested in Atomic Energy as a new form of thermal power, and as you can see from the above, we are active in the reactor power field. It is our conviction that in time nuclear power will be more than competitive with that from conventional fossil fuels.

Answering your specific questions:

1. We are in general agreement with the three major objectives of the program. The achievement of competitive nuclear power will depend on certain technological breakthroughs in the areas of higher temperatures, of reprocessing, and also possibly in the use of plutonium as a fuel. It is impossible to forecast the timing of such breakthroughs. They all might come in a few years. On the other hand, 1 or 2 may encounter a long period of delays and disappointments. Under these circumstances, it does not seem realistic to name the year of achievement in stating the objective. Therefore, in stating the first objective we suggest that "by 1970" be omitted, and "as rapidly as reasonable annual expenditures for research and development will permit" be substituted. If you wish to be more specific, the order of the annual expenditure can be given. Competitive nuclear power in high-cost free-world nations either exists or is very close, today, and only minor technological progress is necessary for achievement. We are confident this objective will be achieved in a few years, and would suggest that the timing be moved up by omitting "by 1968" and substituting "within the decade." In the third objective, we interpret the word "leadership" to mean leadership in the technology necessary to achieve competitive nuclear power. We do not regard the construction of numerous large uneconomic plants, as recently proposed, as constituting leadership. While it is necessary to construct uneconomic or noncompetitive plants in order to develop the art, they should be kept as small as is consistent with the objectives. This observation applies to private industry as well as to the Commission or to the Federal Government.

2. We find we are in general agreement with the general technical objectives as stated. We particularly wish to commend the inclusion of higher temperature steam, cheaper reprocessing, and the use of plutonium as a fuel. It is questionable whether we can achieve competitive nuclear power with 1910 steam cycles. While there have been efforts to increase temperatures, by certain manufacturers, it has seemed to us that the Commission has been slow in realizing that higher temperatures are essential, and in sponsoring a broad research program to this end. We are glad to see that this feature is receiving proper recognition. Similarly, the cost of reprocessing must be reduced. There are numerous avenues of approach to this end, and the Commission should sponsor a broad program. The military market for plutonium does not provide a sound basis for peacetime power costs. Other uses for plutonium must be developed and certainly its use as a fuel must be explored with a broad program of research.

3. Concerning the scope of the technological program, we find that we particularly are in agreement with enlargement of the research and development effort in the above three areas. Also, we are in agreement that the objective is not power, per se, but technological progress.

4. We would like to see "high temperature" or "superheated" appear more frequently in the list of reactors.

5. We believe the cost estimates must be flexible, and find no disagreement.

6. We believe the policies on organization and administration will adequately implement the positive leadership required for success of the program.

There should be no difficulty in obtaining satisfactory proposals from private industry where there is a reasonable prospect of the reactor becoming competitive. The difficulty will be encountered where there is a disagreement as to the prospects. A limited participation by private industry may still be possible, by increasing assistance from the Commission along Shippingport lines. Where no participation by private industry appears possible, and the Commission wishes to demonstrate the reactor full scale, then construction and operation by the Commission appears warranted.

We feel you have covered the types and amounts of assistance for both domestic and foreign programs fairly comprehensively, and have gone about as far in this direction as would be accepted by the public.

We appreciate the opportunity of giving our views on these matters, and trust you will find them helpful.

Sincerely yours,

DAVID B. SLOAN, *President.*

THE H. K. FERGUSON CO., INC.,
Cleveland, Ohio, November 19, 1958.

Mr. JAMES T. RAMEY,
Executive Director, Joint Committee on Atomic Energy,
United States Capitol, Washington, D. C.

DEAR MR. RAMEY: In answer to your inquiry, I should like to submit the following comments on the Joint Committee print entitled, "Proposed Expanded Civilian Nuclear Reactor Program," dated August 1958.

As a general comment, I believe this to be a feasible program for advancing the United States atomic energy position in the world today, both at home and abroad. As with any program, there are individual points which one might well have done in a slightly different manner, but this is an effective program which, if competently and enthusiastically administered, can hasten the day when competitive nuclear power will be a reality.

With regard to the individual questions on which you solicited comments, I should like to take them in order.

(1) My one suggestion concerning the major objectives is that the time scale be shortened. I think we should try for 10 mill power which would be competitive in many foreign markets by 1963 and we should have a goal of 8 mill power, which would be competitive in the high-cost regions of the United States, by 1965. Admittedly, these are very rigorous goals relative to those set forth in the program, but I firmly believe that only by having truly rigorous goals can we engender the effort and enthusiasm required to reach these objectives. I think one of the great problems in the program today is the feeling that economic power will come along by 1970—a date 12 years in the future. Therefore, there is no great urgency to reduce costs; rather, a disproportionate amount of effort is expended on getting new and superefficient designs and too little effort is expended in reducing the capital and operating costs of the present proven designs. From here on, it seems to me, the major goal of the civilian power program is an economic one. Thus, it would be wise to tailor the goal to encourage economic development to a maximum. By concentrating a major effort or developing economically competitive power in high-cost areas of the United States with proven types of reactors, the day when the atomic energy industry will be self-supporting will be hastened. The arrival of this day will provide industry with the money and incentive to push the development of advanced types of reactors now being studied by the reactor research program. While these shorter dates are admittedly rigorous, I do not believe them to be impossible, and I do believe that the size of the United States civilian power effort is such under the proposed program that there is a sporting change of reaching them.

(2) and (3) I have no comments on items 2 and 3. They seem to be quite adequate.

(4) Here it seems to me it would be most desirable to add the construction of three 25- to 75-megawatt reactors of proven design in the 1959 to 1960 period. These reactors would probably not cost over $10 million in the aggregate. I believe they would make two contributions. First, they could well prove that the pressurized water, boiling water, and organic moderated types can be competi-

tive in the process steam field, and if this proved true it would immediately open up to the reactor business an annual potential market of 50 to 100 units. This is the sort of market on which a true nuclear industry can be built. Secondly, this size of reactor could well be used to rapidly develop standard components. All carbon-steel heat exchangers, carbon-steel pumps, and other standard equipment of this type could at small expense be tried out on these plants. Mistakes would be $100,000 mistakes—not multimillion-dollar mistakes as they are in a 500- to 700-megawatt reactor.

(5) I believe the cost estimates are quite adequate for the purpose of this study.

(6) I have no comment on this item.

(7) It would be well to consider the possibility, should further assistance prove necessary, of outlining a subsidy program for domestic reactors somewhat similar to that set forth in the EURATOM program; namely, a payment toward capital costs in excess of those of fossil fueled plants; and some sort of sliding scale subsidy on fuel elements on the order of the air-mail subsidy rather than on the order of the maritime subsidy. It would seem that this type of subsidy would go far toward encouraging the construction of reactors under a program which would maximize private contributions and minimize Government contributions, should the current proposed program fail to result in competitive nuclear power at an early date.

Sincerely,

EDWARD L. HELLER,
Chief Engineer for Nuclear Projects.

JACKSON & MORELAND, INC.,
Boston, Mass., October 20, 1958.

Mr. JAMES T. RAMEY,
Executive Director, Joint Committee on Atomic Energy,
Congress of the United States, Washington, D. C.

DEAR MR. RAMEY: We have read with interest your August 21, 1958, letter, together with the attached staff memorandum describing a proposed expanded civilian nuclear-power program. Our comments on the specific questions in your letter are as follows:

1. The three major objectives of the program, as outlined, are very good. However, we suggest that the first objective might be more specifically worded, for example:

"(*a*) Achieve and demonstrate in the United States nuclear power competitive in total cost per kilowatt-hour (including operating costs and fixed charges) by 1970. The goal shall be considered achieved if the nuclear plants developed under the program constitute or are competitive with 10 percent of the total thermal capacity added in 1970."

2. The general technical objectives set forth mainly involve the refinement of component parts for systems which have already been developed or are in the process of development. It appears doubtful to us that refinement of these systems can achieve the necessary reduction in cost of electric power, because these systems inherently are limited to rather low thermal efficiencies. We believe that the scope of the technical objectives should be increased to permit the development of simple, high-energy density and high-efficiency systems with major emphasis on lowering capital cost rather than decreasing fuel cost. We would suggest such technical objectives as—

(*a*) Cycle simplification by greater emphasis on using the reactor coolant as the prime-mover working medium.

(*b*) Development of high-energy density systems for both the reactor and prime mover.

(*c*) Low enrichment fuel elements capable of withstanding clad temperatures of 1,600°–1,800° F. and burnup to 10,000 megawatt-days per metric ton of uranium or other fuel.

3. The scope of the technological program should be changed to be consistent with the modifications proposed in the preceding paragraph for the general technical objectives.

4. In our opinion, a high-pressure, high-temperature, light-water-moderated, gas-cooled reactor in combination with a closed-cycle gas turbine is worthy of serious consideration for new undertakings. It should be included in the proposed list of reactors for prototype and full-scale develop-

ment, even though this might require that less emphasis be placed on some of the other reactor types.

5. In view of the published data and studies of reactor systems which have been undertaken, we believe that the cost estimates shown are reasonable. In large plant sizes, unless some of the systems show a capital cost in the order of $200 per kilowatt, we do not believe that economical competition with conventional plants by 1970 will be realized. On this point, we believe the appropriation is excessive, because $500 per kilowatt is unwarranted except for small, prototype, or experimental plants.

6. The policies on organization and administration are realistic and would provide a good base on which to start the program. The AEC would clearly be responsible for the direction of the program and the extent to which various systems should receive support. However, we believe the emphasis on reasonably well demonstrated technology and the consequent restriction on research and development will tend to stifle the innovation necessary for rapid attainment of the goal of economical nuclear power. Because the program is developmental in nature, it would seem that new types of systems which do involve research and development work should not be excluded.

7. In the event that the proposed incentives do not prove adequate support for the civilian nuclear-power program, a direct dollar subsidy may become necessary.

Thank you for this opportunity to comment on the proposed expanded civilian nuclear-power program.

Sincerely,

JOHN R. COFFIN.

J. A. JONES CONSTRUCTION CO.
Charlotte, N. C., August 25, 1958.

Mr. JAMES T. RAMEY,
Executive Director, Joint Committee on Atomic Energy,
Washington, D. C.

DEAR MR. RAMEY: In answer to your inquiry of August 21, we will answer as per the questions raised.

1. The three major objectives are certainly clear enough and are comprehensive enough for the purposes of this program.

2. The same answer applies to this question. The technical objectives as outlined would certainly include any incidental or related objectives that would develop.

3. Certainly adequate.

4. I may be alone in this, but I would recommend the AEC build a power reactor at each of its major plants that would not only supply a large amount of power for its own operation, but these power reactors could be changed from time to time as new methods and processes are discovered so as to give private industry as quickly as possible the results of the use of newly discovered processes and equipment. These power reactors at AEC's major plants would, therefore, have a dual purpose not only of providing power, but as a demonstration of the development of power from nuclear plants.

5. The cost estimates may or may not be correct. They certainly are an educated guess.

6. In my opinion, the AEC must furnish positive leadership in this field and make it one of their major objectives.

7. Believe that this should depend on the development of the program and a new look at it after several years of experience in the program.

Yours sincerely,

EDWIN L. JONES.

[Telegram]

OAKLAND, CALIF., *November 13.*

JAMES T. RAMEY,
Executive Director, Joint Committee on Atomic Energy,
Congress of the United States, Washington, D. C.:

Have carefully studied proposed expanded civilian nuclear-power program and have no comments to add at this time.

KAISER ENGINEERS.
PATRICK J. SELAK.

PRICHARD-WARREN-LOWE ASSOCIATES,
Washington, D. C., October 17, 1958.

Mr. JAMES T. RAMEY,
Executive Director, Joint Committee on Atomic Energy,
Congress of the United States, Washington, D. C.

DEAR MR. RAMEY: This is in reply to your request of August 21, 1958, for views and comments on the proposed expanded civilian nuclear reactor program.

Before replying to your specific questions, we have one general comment.

Now that almost 5 years of the original 5-year power reactor development program have passed, it is important to take stock of the accomplishments made under this program before attempting to redefine objectives or outline a new program.

Much excellent work has been carried out, and much data acquired during the last 5 years on several reactor systems. Most important, however, several reactors have been put into operation, providing for the first time an opportunity to acquire actual operating experience needed to determine technical and economic feasibility. Also, design and construction of other reactors has progressed sufficiently far to provide some realistic capital cost data and preliminary operating cost estimates.

This work and experience have demonstrated that the task of developing economic nuclear power is more costly and time consuming than was recognized by many at the beginning of the 5-year program. The difficulty of the task, among other things, has resulted in the costs of several large projects considerably exceeding the original estimates.

It is very important in establishing a new program to profit as much as practical from the results obtained from the old program. Both the existing and proposed programs are large and complex, and it is not apparent from the limited information and analysis available that the results of the 5-year program wholly reaffirm the hopeful prospects previously visualized for nuclear power, or justify the size and nature of the proposed program.

To evaluate the prospects and determine a new program therefore require, in our opinion, careful reporting and detailed analysis by those skilled in the art, and by those who will eventually provide funds for the economic application of the various reactor concepts when these have been developed. Some of this has been done, but not enough to establish a new program comparable in size to the original Manhattan project ($1.5 to $2 billion).

Comments on your questions follows:

"1. Do you agree with the three major objectives (p. 4) of the program? If not, what changes would you recommend?"

The general objectives are assumed to be worthwhile, and we believe it is reasonable to expect that they can be accomplished in the time allotted. The benefits derived from such accomplishments should, of course, be weighed against the efforts required, as well as balanced against other benefits expected from other national programs competing for these efforts.

It is proper that the Congress establish such objectives, together with an indication of the size of public expenditures which may be justified to accomplish them. It is not feasible nor desirable for Congress to define the nature of the program in detail.

In establishing objectives to demonstrate economic nuclear power, it is necessary to recognize the real purpose of the demonstration, because this will to a large degree determine by whom and how the demonstration should be carried out.

If it is assumed that the real objective is to demonstrate to the United States utility industry so that it will see fit to build and operate nuclear plants, then it is most important that that industry participate in the demonstration, certainly to the extent of providing ground rules and conditions to make the demonstration effective, preferably to the extent of conducting the demonstration.

"2. Are the general technical objectives (p. 5) adequate? If not, what additions or deletions would you recommend?"

The relative importance of these objectives, as well as the existence and importance of others, depends strongly on a careful analysis of the latest experimental data available. Therefore provisions should be made for changing them as indicated desirable by frequent and careful review.

Unfortunately, some of these objectives are not mutually consistent, and must therefore be considered together from time to time and their relative importance established. Also, it is difficult and misleading to consider these general objectives abstractly, without applying them to a specific reactor type. Therefore, it

is suggested that an additional useful approach would be to select a few of the most immediately desirable reactor types, and, after properly analyzing their current development status, identify the technical objectives applying to them.

"3. Please comment on the adequacy of the scope of the technological program (p. 6)."

The scope of the technological program is very difficult to determine. Certainly a broad basic research and development effort is necessary. It is also equally if not more important to design, build, and operate power reactors and their associated systems so that practical experience and know-how can be obtained on all the problems of generating nuclear power.

The inherent inflexibility of a formal reactor program sanctioned in detail by the Congress and others, as was the 5-year program, causes (*a*) unnecessary expenditures for continuing some projects as originally planned which experimental results indicate should be terminated or reoriented, and (*b*) unnecessary delay in undertaking new projects which experience indicates are desirable.

There are strong indications, to be confirmed by additional analyses, that 1 or 2 of the reactor types technically proven under the 5-year program can be made competitive in the next 5 to 7 years. The development of other types is less certain of success, and will require more effort and time. Therefore, the selection of 1 or 2 reactor types for increased development effort could be justified in the interest of saving both time and effort.

"4. In your opinion, is the proposed list of reactors in table I the best list for this program? If not, what changes would you recommend?"

This list is long and includes nine large reactors of different types. While it is understood that it is proposed that only about half of these large reactors will be constructed, as justified by preliminary work, we believe that the overall objectives can be accomplished more rapidly and economically by concentrating on 1, 2, or perhaps 3 different reactor types, rather than on a larger number.

Except for those projects already underway, and 2 or 3 reactor types to be selected, it would thus be desirable, as far as the Government's efforts are concerned, to reduce the work on other types of reactors to studies and experiments preliminary to or involving small reactor experiments or in-pile loop tests.

An intensified effort should be undertaken on the 2 or 3 types selected, to design and construct several small and medium-sized plants of improved design, and to undertake the design and construction of 1 or 2 full-scale plants only when there was demonstrated a reasonably good chance that such large reactors would themselves operate economically.

When the advantages of the construction and operation of a proposed large plant are doubtful, the construction and operation of small or medium-sized plants—as demonstrated by the EBWR, the OMRE, and the Vallecitos boiling reactor—can provide as much if not more useful experience, because of their lower cost, greater operating flexibility, and shorter schedules. This is particularly true if the construction and operation of the smaller plants are carried out under an industry-utility setup, accustomed to interpreting experience gained in light of its true operational and economic significance.

It is disturbing to contemplate the possibility that other large reactors of yet untried concepts may be built on an accelerated basis by the Government, out of phase with their normal development, as was the PWR, especially if there is a chance their costs will significantly exceed economic values.

Now that at least one reactor type, i. e., water type, has been proven technically feasible, and also to have reasonably good prospects of ultimate economic feasibility, there can be little justification for constructing and operating large uneconomic plants of unproven types without first going through the normal and necessary developmental steps which would probably include experimental and small plant construction and operation.

"5. Do you consider the cost estimates (p. 8) to be reasonable? If not, please point out the areas in which you disagree."

Considerable expense can be saved without jeopardizing the possibility of accomplishing the overall objectives by reducing the number of large plants, and by limiting the work on unproven reactor types either to that already committed, or to first phase research and development and experimental plant construction.

Because of the limited amount of skilled industrial manpower available, compared to that needed to build and operate the many types of reactors proposed, it is quite likely that a program of fewer types, but dedicated to advancing these to the economic point, will in fact bring about the demonstration of economic nuclear power sooner than unbridled pursuit of the many types listed in table I.

We note that no mention is made of operating costs for the reactors proposed.

If a number of large, uneconomic plants are built, their out-of-pocket operating costs may be appreciable.

"6. What is your opinion of the policies on organization and administration proposed on page 9? Will they adequately implement the positive leadership required for success of the program?"

The AEC has extensive and valuable background in the conduct of the base program of research and development. It also has limited experience in the direction of reactor experiments and the construction and operation of small reactor plants. However, if the objective is to demonstrate economic power to United States industry, it is important that United States industry, including utilities as well as manufacturers and engineers, participate in the direction of even the experimental and feasibility projects to a greater extent than is indicated in the proposed expanded program. Without this participation, the base program, and certainly the development efforts, may be excessively costly, and industry, whose ultimate participation is inevitable, will not acquire the experience and know-how which come from doing.

If the objective is to demonstrate economic power to foreign industries and governments, it may not be as essential that United States utilities participate. This, however, in our opinion, deserves careful exploration.

In view of this and the AEC's lack of qualified and experienced administrative personnel in the power field, it is impractical to expect the AEC to assume the entire responsibility of selecting demonstration reactors, establishing their construction schedules, and directing their construction and operation.

We believe that a more practical course would be to modify and expand the power reactor demonstration program by offering increased AEC financial support for several small- and medium-sized plants of types largely selected by industry to be built and operated by industry. Such assistance might be applied first on operating expenses, and next, if needed, on capital expenses. We understand this will involve a different interpretation of the "no subsidy" provisions of the 1954 act than has been employed to date. Because these plants will be experimental, expendable, and uneconomic, they may logically be considered part of the research and development effort, and thus their capital expenses supported by AEC funds without a change in the act.

"7. If it should later prove necessary, what other types and amounts of assistance would you recommend for the domestic program? For the foreign program?"

Regarding the domestically oriented program, certain modifications of the power demonstration reactor program should be very helpful, as you have noted, to improve its effectiveness and flexibility. The participation of industry in the selection of reactor types and sizes to be built, and an increased emphasis on improving technically proven types through pilot-plant operation, should provide a reasonable chance of accomplishing economic demonstration in the period desired, and at considerable savings over the proposed program. In commenting on No. 6 above, we suggest that an expanded demonstration program is desirable and that financial support of it by AEC could be accomplished through a logical interpretation of the existing statutes.

We also believe that AEC assistance on worthy reactor projects in the form of research and development efforts should be supplied without firm commitments on the part of industry to build large plants whose technical and economic feasibility can only be established through the research and development. A straight cost-sharing arrangement between AEC and industry would probably be a more practical approach, and would also place the emphasis on the need to acquire experience and know-how, rather than on an expensive and misleading "kilowatt race."

The proposed assistance to other countries would appear to be quite adequate, and should, in our opinion, be clearly limited timewise and also in regard to materials, guaranties, and services subsidized. Similar assistance to domestic projects would be quite stimulating.

We hope these comments will be useful. We wish to emphasize our awareness that the development of economic nuclear power is proving to be a difficult task and that designing a sound, well-rounded program in terms of the motivations for expanded and accelerated efforts is not easy.

Yours truly,

JAMES K. PICKARD.

SANDERSON & PORTER,
New York, N. Y., November 7, 1958.

JOINT COMMITTEE ON ATOMIC ENERGY,
Congress of the United States,
Capitol Building, Washington, D. C.
(Attention: Mr. James T. Ramey, executive director.)

GENTLEMEN: Our letter of October 30, 1958, commenting on the Joint Committee's print entitled "Proposed Expanded Civilian Nuclear Reactor Program," dated August 1958, contains an error on page 2. The last line of the first paragraph under 2, general technical objective, should read: "or plutonium recycle fast breeders and thermal breeders and thorium breeder reactors."

On page 3, the last paragraph, the eighth line, should have inserted the word "not" after "will" to make it read: "This gas temperature will not result in high-temperature steam."

Will you please make these corrections and accept our apologies for the errors?

Sincerely,

SANDERSON & PORTER.

SANDERSON & PORTER,
New York, N. Y., October 30, 1958.

JOINT COMMITTEE ON ATOMIC ENERGY,
Congress of the United States,
Capitol Building, Washington, D. C.
(Attention: Mr. James T. Ramey, Executive Director.)

GENTLEMEN: This letter is in reply to your request of August 21 for our views and comments on the Joint Committee's print entitled "Proposed Expanded Civilian Nuclear Reactor Program," dated August 1958.

Before expressing our views and comments we would take the liberty of outlining the background of this firm and our present position in the nuclear power field in order that you may place the proper interpretation on anything that we might say.

Sanderson & Porter are engineers and constructors and have operated as a partnership, serving the power-producing industry in this country and abroad, for the past 60 years. During this time Sanderson & Porter have conceived and pioneered many of the design concepts in use in central station plants today. In keeping abreast with current developments we pioneered the study of the closed cycle gas turbine powerplant by the Corps of Engineers and the AEC from basic designs proposed by us. From this and other works we developed a concept of a high temperature, gas-cooled reactor, which, in the course of design, resulted in the pebble bed reactor as a heat source for a modern high pressure, high temperature, electric generating station.

We initiated at our own expense a full study of this concept which, when reported to the AEC and industry, created a widespread interest. Recently we completed, under an AEC contract, a comprehensive feasibility study of a 125 electrical megawatts central station powerplant using the pebble bed reactor, and the findings brought an additional AEC contract for further study and limited fuel element development. The attached report entitled "A High Temperature Pebble Bed Reactor for Central Station Use" briefly describes this system and a 125 electrical megawatts central station powerplant.

Against this background we would present our comments on the proposed expanded civilian nuclear reactor program.

1. Program objectives

We agree with the program objective of providing competitive nuclear power within 10 or 12 years. We believe, however, that the domestic and foreign programs are one and the same. Obviously, because of the high cost of fuel in foreign countries, plants being developed will be competitive abroad and can be sold for export before they become competitive in the United States.

With this thought in mind a single objective can be stated:

Fortify the position of leadership of the United States in the peaceful application of atomic energy by achieving and demonstrating nuclear power, competitive in cost with that produced from fossil-fuel-fired plants of equivalent output in the United States by 1970.

2. General technical objective

We believe the general technical objective necessary to accomplish the listed program objectives will require the development of fuel cycles and reactors capable of producing high temperature working fluid. This immediately removes natural metallic uranium from consideration and dictates the use of fuel in ceramic form such as the oxide or carbide. Also, in our opinion, only fuel cycles offering the possibility of a high conversion ratio or breeding should be considered. This eliminates U–235 as a burner and dictates that future efforts should be directed toward solution of the problems connected with the U–235, U–238, and U–233—Th–232 fuel cycles, or plutonium recycle fast breeders and thorium breeder reactors.

Fuel cycles and reactors which do not meet these breeder objectives should be deemphasized and the money made available by cancellation of projects should be applied to the more advanced types.

3. Technological program

We are in general agreement with the technological program.

4. Proposed reactor types (table I)

We are of the opinion that any list of reactor types to be developed over the next 10 years must be flexible and subject to constant change to keep pace with the art which is continually changing. Close watch of the direction of these changes by the appropriate technical body within the AEC is essential for the success of the program.

We would suggest that the table be set up to clarify objectives. First, list reactors of established type that can be built now for use in gross power demonstration and immediate export sale. These include the pressurized water, boiling water, and organic moderated reactors.

Then list experimental reactors of new types and future power demonstration reactors developed from these experimental types. Reactors in this category are experimental reactors and, in some instances, reactor experiments. Selection of these requires a great deal of judgment. As a first requirement they should obviously show promise of complying with the principal objective, i. e., competitive power. We need a yardstick to show how competitive each type is. Also, we want to examine the potentials of each type with respect to temperature of operation and use of a fuel cycle which will result in breeding. We do not believe anyone is in any position at this time to postulate which of these reactors will be successful enough to justify a full-scale powerplant and would therefore suggest that these reactors be removed from this category.

Process reactors do not, in our opinion, belong in the list of experimental power reactors or reactor experiments. However, if they are to be covered they should be given more emphasis.

In view of the general technical objective which requires high-temperature steam, we are convinced that the gas-cooled reactor type is not being given enough emphasis. The second item in table I is a gas-cooled graphite moderated powerplant listed at 40 megawatts output. The AEC news release requesting proposals for its construction spelled out that the "proposed reactor be designed to operate with a gas temperature of at least 1,000° F.," implying this to be an acceptable upper limit. This gas temperature will result in high-temperature steam by present industry standards. In fact, 1,000° F. gas temperature can just produce 850 lb./900° steam, which conditions are obsolete for large size units. By today's standards 1,450 lb./1,000° F. steam is obsolescent, with 1.450 lb./1,000°/1,000° reheat respresenting the lower limit of acceptable standards. In order to produce 1,450 lb./1,000° F. steam a 1,200° F. reactor fluid temperature is required.

Going on to item 16 we find a high-temperature gas-cooled graphite or heavy water moderated reactor plant of 200 eMW being produced in 1961–66. For such a plant, started in 1961, steam should approach supercritical conditions of 3,500 lb./1,150°/1,050° reheat. This will require gas temperatures of the order of 1,400° F. Where is the experimental reactor preceding construction of this plant? It is certainly not the 40-megawatt powerplant of item 2.

With further reference to the gas-cooled reactor program, it is generally recognized that the gas turbine offers promise as power conversion equipment in such systems. While the size of the gas turbine is only limited by the unit size of the generator it drives, we are of the opinion that its most useful field of application will be in outputs of the order of 20 to 50 megawatts, a range where economical steam conditions are not readily attained. We believe,

therefore, that the gas turbine nuclear powerplant should be included in a list of promising reactor types, even if it does not go beyond the feasibility study stage.

5. Estimated costs

With respect to the estimated cost of this expanded program, we offer this approach. Based on conservative estimates (Electrical World, September 1958), it is expected that the power-producing industry will spend $18,721 million in nuclear, hydro, and fossil fuel plants in the next 7 years. The American Management Association survey of June 1958 reports that the research and development budget for 1958 as reported by 833 companies will be 2¼ percent of 1958 sales.

Research and development expenditures have shown a constant trend upward, so use of the 1958 figure of 2¼ percent is conservative. Assigning 2¼ percent of the projected expenditures by the power-producing industry for research and development for a new heat source, we find that expenditures should amount to $420 million for the next 7 years, or $600 million over the next 10 years. This is approximately half of the estimate of the expanded program. Expenditure of the full amount in your report will obviously result in more rapid development.

6. Organizations and administration of program

We concur with your statements regarding the organization and administration of the program. We believe it is the responsibility of the AEC to provide the basic research and development and construct experimental reactors. If this is not done, the reactor types that will reach maturity will be limited to the few that can be financed by private firms who must, of economic necessity, limit the extent of their activities. We would also recommend that the program be conducted so as to build a broad base of manufacturing and engineering firms with nuclear reactor experience.

7. Other types and amounts of assistance

As noted under the previous item, we believe the only assistance the Government need provide is basic research and construction of experimental reactors or reactor experiments by Government laboratories or through contracts with private firms. We believe that when a reactor type demonstrates that it will produce competitive nuclear power, industry will build it.

We appreciate the privilege of commenting on your proposed expanded program and hope that our remarks have been helpful.

Sincerely,

SANDERSON & PORTER.

A HIGH-TEMPERATURE, GAS-CYCLE, PEBBLE-BED REACTOR FOR CENTRAL-STATION USE

By S. T. Robinson and R. F. Benenati, Sanderson & Porter, New York, N. Y.

ABSTRACT

A high-temperature, gas-cycle, pebble-bed reactor is described, together with the specific design and economics of a 125-electrical-megawatt central-station powerplant. The nuclear characteristics of the system are presented, together with a discussion of fuel cycles, fuel-element types, and development problems.

INTRODUCTION

A high-temperature, gas-cycle, pebble-bed reactor (PBR) has been under study by Sanderson & Porter and Alco Products, Inc., for the past 18 months. This reactor concept originated from extensive studies made over the past 5 years by Sanderson & Porter of power-producing equipment and particularly in connection with studies of the closed-cycle, gas-turbine, nuclear powerplant.

The concept is not new, having been originally proposed in 1944. The reactor type is being developed jointly by the Atomic Energy Commission and Bureau of Mines for process heat and by the Brown-Boveri-Krupp group in Germany for central-station use. The high-temperature, gas-cycle reactor is also one of the future generation reactors under development by the United Kingdom Atomic Energy Authority.

The pebble-bed reactor can be built as a single- or two-region reactor. All core materials, including the fuel elements, are graphite. The reactor working fluid is helium. This combination of graphite, a high-temperature refrac-

tory, and helium, an inert gas, effectively removes all practical temperature limitations from the system. Not being temperature limited, it is possible to generate steam suitable for use with modern steam-turbine generating equipment. Since the structure and coolant have extremely low parasitic capture, the system has good neutron economy. A high conversion ratio can be attained, and breeding appears possible in certain sizes and configurations.

The fuel system of this reactor has been selected with the object of economy in the production of electrical power. Fuel elements consist of graphite spheres containing fissile and/or fertile material, and are randomly packed in the reactor. This is a material form that is intermediate between the carefully fabricated, precisely located, and firmly supported rods, tubes, and plates used in most reactors and the completely unfinished and dispersed bulk material used in a homogeneous or a slurry reactor. Incorporation of the fissile and fertile material in graphite, from which heat is removed by helium, permits operation at high temperature, which is the basic objective of the design. Use of fuel in spherical form offers a comparatively simple method of fabrication which can be effected by mass-production methods. Fuel in this form is amenable to simple handling techniques in loading and unloading. While unclad fuel elements will result in economies in fabrication, head-end treatment prior to reprocessing, and should permit a high burnup, they will allow fission products to diffuse into the gas stream. The expected activity in the primary system is somewhere between that in the primary system of a pressurized-water reactor and an aqueous homogeneous reactor.

Whether such an activity level can be tolerated from the standpoint of maintenance, or whether it must be reduced by means of some type of impervious refractory coating on the fuel elements, is the major question confronting designs of reactors of this type.

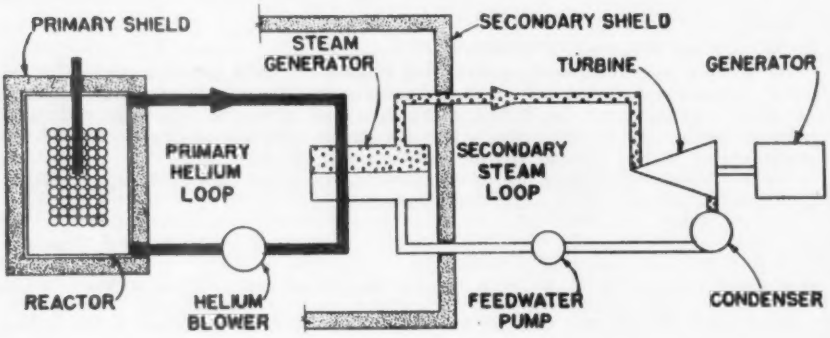

FIGURE 1.

The pebble-bed reactor steam powerplant is designed using a primary and secondary loop, as shown in figure 1. The primary loop is the helium loop in which heat of fission is transported from the reactor to a steam generator. This steam is used in a secondary loop to generate electricity in conventional steam-turbine generating equipment. The reactor is enclosed in a primary shield and the steam generators and blowers within a secondary shield. These items, together with all auxiliary gas-handling equipment, are enclosed in a containment vessel. Since there is no activity in the secondary system, the turbogenerating plant can be housed in the conventional manner.

The compatibility of the high-temperature, gas-cycle reactor with modern steam plants can be seen from inspection of figure 2, showing the percent of heat transferred versus temperature for a 1,450-pound/1,000° F. nonreheat and a 3,500-pound/1,100°/1,500° reheat supercritical plant, as limits, against temperature. The gas temperature range shown has been selected as being high enough to result in economical steam generating equipment but low enough to be within the limits of present design practices.

The pebble-bed-reactor has a number of basic advantages which lead to low production costs when compared to present nuclear-plant designs. Neither the core structure nor fuel and blanket elements require high precision manufacturing methods. The core structure, fuel and blanket elements and working fluid

are all capable of operation at extremely high temperatures and, therefore, are not critical to hot spots and possible burnout. The use of helium, an inert gas, as a working fluid eliminates the need for costly corrosion-resistant construction materials or cladding. The use of fuel and blanket elements in a form amenable to handling by fluid-handling techniques reduces the costs associated with loading and unloading mechanisms. Since power can be produced in conventional steam-turbine generating equipment, a premium need not be paid for special low-pressure turbine types.

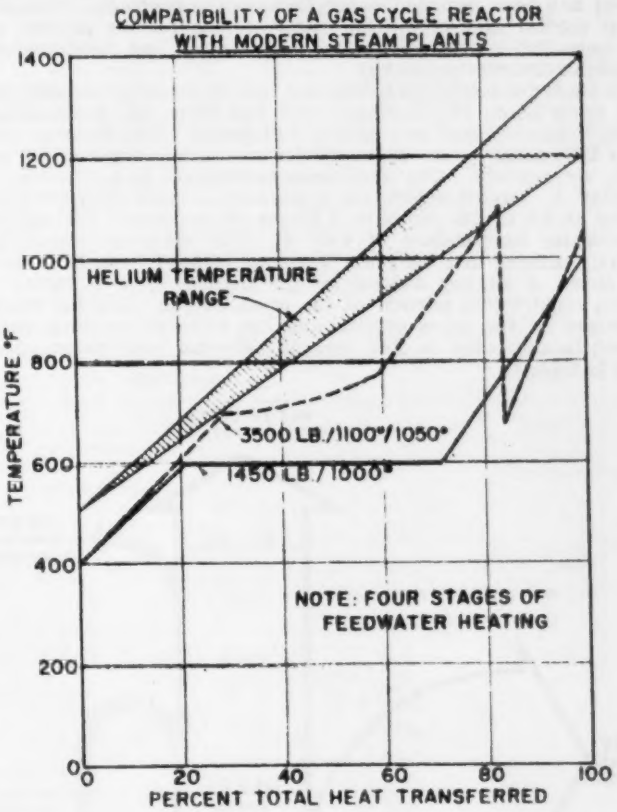

FIGURE 2.

The problems associated with its design are those of handling a high-temperature gas as a heat-transport fluid and the problem present in virtually all reactor systems of a hot or radioactive primary loop.

Studies made to date do not indicate any restriction with respect to the fuel cycle except that a partially enriched core is required to achieve a reasonable capital cost and fuel investment. Pebble-bed reactor fuel systems investigated have been U–235 burners and U–233-thorium converters. A U–233-thorium breeder and U–235-plutonium converter are presently under study. The U–233-thorium system has been questioned because of the present state of availability of these materials. However, this cycle has the desirable feature of permitting the operator to purchase his fuel supply—i. e., thorium—on the open market after establishing a full U–233 loading. Availability of materials for the U–235-plutonium system is better, and the system offers the possibility of the use of natural and/or depleted uranium as the feed material.

In the final analysis, the attractiveness of any nuclear reactor system is reflected in production costs, as all advantages and disadvantages of a particular system can be expressed in terms of capital and operating costs. Studies of the

pebble-bed reactor indicate that it can produce power at a cost competitive with modern fossil-fuel-fired stations of equivalent output, thereby justifying the belief that this system warrants the research and development required to bring it to the point where a central-station plant of modest output can be constructed.

DESIGN STUDY OF A 125-ELECTRICAL-MEGAWATT PEBBLE-BED REACTOR STEAM POWERPLANT

During the past 6 months, a 125-electrical-megawatt pebble-bed reactor steam powerplant has been designed under Commission contract. This design established the capital and production costs of this reactor system, pointed out areas of potential improvements and the research and development necessary to make such a system operational.

The 125-electrical-megawatt pebble-bed reactor steam powerplant, as presently designed, operates on the thorium-U–233 fuel cycle, has a conversion ratio of 0.863, and a hundred-day core life at full power. The thermal output of the reactor is 337.1 megawatts. Reactor inlet and outlet temperatures are 550° and 1,250° F., respectively. The associated powerplant is a 125-megawatt, 1,450-pound/1,000° F., tandem compound, triple-flow exhaust, nonreheat, turbine unit exhausting at 1.5 inches Hg with 4 stages of feed-water heating, producing a final feed-water temperature of 400° F. The maximum capability is 126.7 megawatts, resulting in a net plant heat rate of 9,077 British thermal units per kilowatt-hour. A Sankey diagram of the thermal cycle is shown in figure 3. Auxiliaries require 8.85 percent of the gross output, and the ratio of pumping power to heat transferred in the boiler is 2.47 percent. Reactor and system characteristics are given in table I.

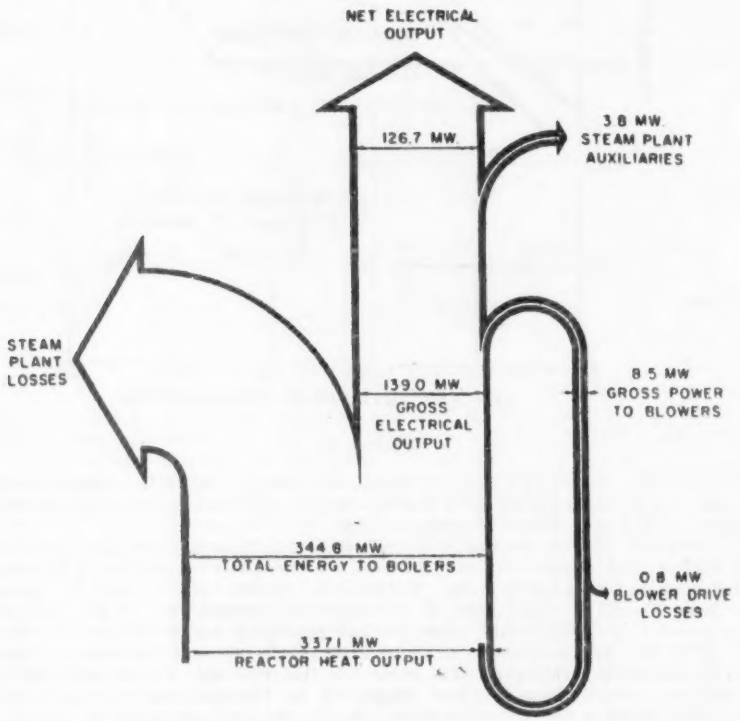

FIGURE 3.

TABLE I.—*125 electric megawatt PBR pertinent plant data*

General:		
Reactor output	megawatts	337.15.
Heat from blowers	do	7.67.
Heat to steam generators	do	344.82.
Capability, gross/net	do	139.03/126.75.
Auxiliary power	do	12.28.
Heat rate, gross/net	British thermal units per kilowatt-hour	8464/9077.
Containment vessel:		
Size		75 feet diameter by 94 feet high.
Wall thickness		1 inch.
Design pressure	pounds per square inch, gage	35.
Shielding		Concrete.
Thickness		1 foot and 2½ feet.
Reactor vessel:		
Size		13 feet 8 inches by 21 feet.
Wall thickness		5.5 inches.
End thickness		2.75 inches.
Thermal shield thickness		2 inches.
Reactor core:		
Equivalent diameter	feet	9.
Height	do	8.1.
Voidage	percent	29.
Moderator and structure		Graphite.
Fixed moderator volume	$feet^3$	130.
Ball bed volume	$feet^3$	383.
Reactor blanket:		
Equivalent thickness	feet	1.33.
Height	do	8.1.
Voidage	percent	39.
Ball bed volume	$feet^3$	496.

Fuel elements	Core	Blanket
Form	Spherical	Spherical
Diameter (inches)	1.5	1.5
Number	228,600	296,250
Composition, by weight (grams):		
Graphite	48.49	45.28
ThO_2	4.94	45.28
UO_2	.45	
Total	53.88	90.56

Nuclear:		
Core C/Th/U atom ratio		3745/11/1.
Blanket C/Th atom ratio		22/1.
Critical mass (1,200° F., eq. Xe), Kg. U-233		60.2.
U-233 loading	kilograms	90.2.
Th-232 loading in core	do	992.2.
Th-232 loading in blanket	do	11,780.
Fuel burnup rate, kilogram per megawatt year		0.48.
Initial capture to fission ratio		0.257.
Fraction of epithermal fissions		0.372.
Initial breeding ratio:		
Core		0.477.
Blanket		0.353.
Total		0.830.
Average BR over core lifetime		0.863.
Average power density, watts per cubic centimeter		23.7.
Atom burnup (percent total atoms):		
Core (after 100 days)		0.021.
Blanket (after 1,000 days)		0.006.
Temperature coefficient		-2.7 by 10^{-5}/° F.
Initial multiplication factor:		
Keff (1200° F., eq. Xe)[1]		1.100.
Keff (77° F., no Xe)		1.204.
Average thermal flux at startup, n/cm^2-sec		1.3 by 10^{14}.
Average thermal flux, after 100 days, n/cm^2-sec		2.2 by 10^{14}.
Control rods.		
Number		12.
O. D	inches	4.
I. D	do	3½.
Material		Haynes-25.
Length	inches	99.
Weight	pounds	83.
Drive		Electric motor.
Reactivity worth, initial		17.3%.

TABLE I.—*125 electric megawatt PBR pertinent plant data*—Continued

Thermal and fluid dynamic characteristics:		
Design power level	megawatts	350.
Design pressure level	pounds per square inch, absolute	1,000.
Design helium flow	pounds per hour	1,360,000.
Volumetric heat generation, megawatts/feet [3] ball bed		0.915.
Temperature:		
Reactor inlet	degrees Fahrenheit	550.
Reactor outlet	do	1,250.
Core outlet, average	do	1,540.
Blanket outlet, average	do	561.
Fuel element surface, maximum	do	2,170.
Fuel element center, maximum	do	2,440.
Operating power level	megawatts	337.
Core contribution [2]	do	291.5.
Blanket contribution [2]	do	45.5.
Operating pressure level	pounds per square inch, absolute	965.
Operating helium flow	pounds per hour	1,343,000.
Core pressure drop	pounds per square inch	15.5.
Helium blowers (3):		
Capacity	cubic feet per minute	20,000.
Main drive		3,500 horsepower, 3,600 revolutions per minute.
Emergency drive		30 horsepower, 450 revolutions per minute.
Total pumping power	kilowatts	8,536.
Steam generators (3):		
Size		8 feet 6 inches diameter, 36 feet high.
Steam pressure and temperature		1,450 pounds per square inch, gage; 1,000° F.
Steam flow per generator		352,000 pounds per hour.
Feedwater temperature		400° F.
Number of feedwater heaters		4.
Helium temperatures		1,207 degrees F. in; 500° F. out.

[1] Equivalent bare homogenized core model.
[2] At equilibrium conditions, after 10 core lifetimes.

The 125 electrical megawatts pebble bed reactor is illustrated in figure 4. It is of all graphite construction within the thermal shield, with the core elements contained in seven vertical channels and the blanket elements contained in an annular ring formed by the core channel structure and the thermal shield. Heat is removed by a helium stream flowing downwards through the core and blanket in parallel. Control is effected by 12 top-driven control rods which run in the core channel structure around the central channel. Helium enters and leaves the reactor through three coaxial pipes at the bottom of the vessel. Fuel is loaded through multiple loading tubes at the top of the reactor vessel and unloaded through a single discharge valve at the bottom. The design of this unloading valve is unique in that a single valve is used to unload the core regions and blanket in sequence. The valve meters the ball flow, is positive in opening and closing and jamming is impossible.

All permanent graphite parts in the reactor are treated with an impervious coating, such as silicon carbide, to prevent irreparable damage which might result from a steam leak into the primary system during operation.

The reactor pressure vessel is cylindrical in shape having hemispherical heads at each end. The inside diameter is 12 feet 11 inches and the overall height is 21 feet. It is pierced by a total of 29 penetrations, 25 of which are minor in size.

The 7 fuel chambers are randomly loaded with 1½-inch graphite balls containing 10 weight percent of fertile and fissile material in the form of thorium and uranium-oxides in the ratio of 11 : 1. The single blanket region is randomly loaded with 1½-inch graphite balls containing 50 weight percent of fertile material in the form of thorium oxide. The core loading is 90.2 kilograms of U–233. Based on the U–233 loading in the core and the design reactor output, the power density is 3,880 t kw/kg. Based on the thorium and U–233 loading in core and blanket at equilibrium operating conditions, i. e., after 10 core loadings, and the net system output, the investment in fissile and fertile material is $18.60 per electrical kilowatt.

The reactor and the entire primary loop are located in a steel containment vessel 75 feet in diameter and 94 feet high shielded above grade with a thin skin of concrete. This vessel and the primary loop equipment are shown in figure 5.

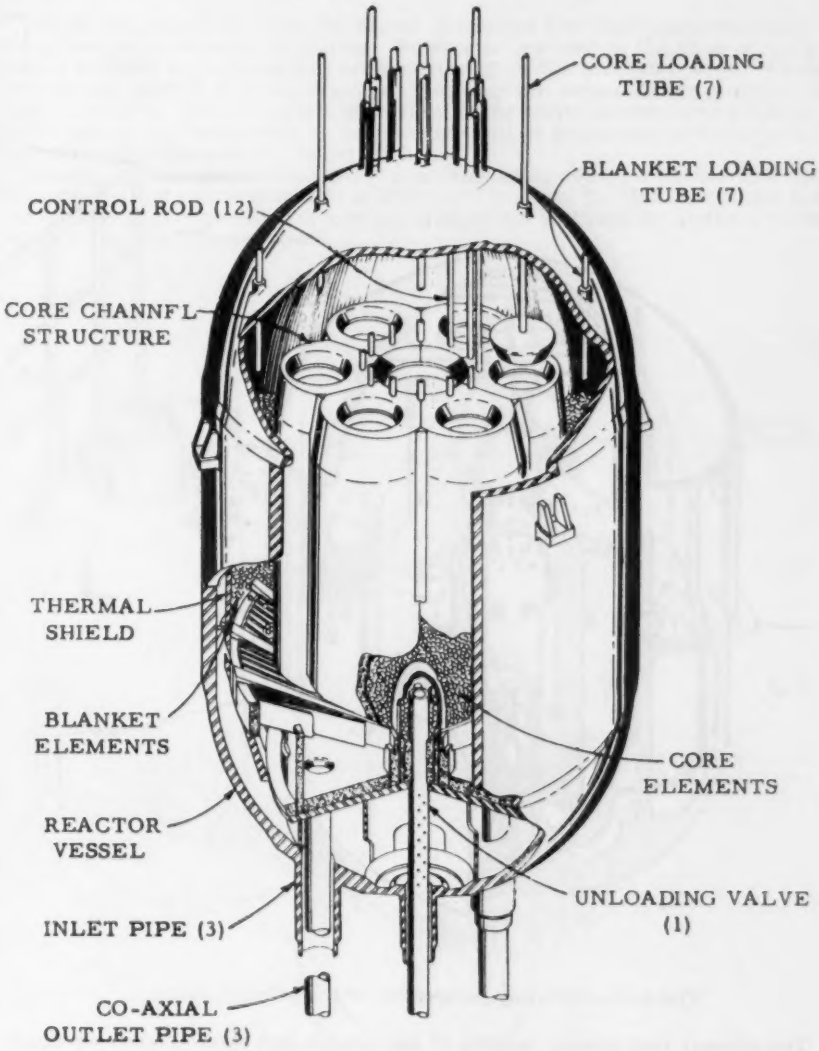

FIGURE 4.—125 electrical megawatt pebble bed reactor.

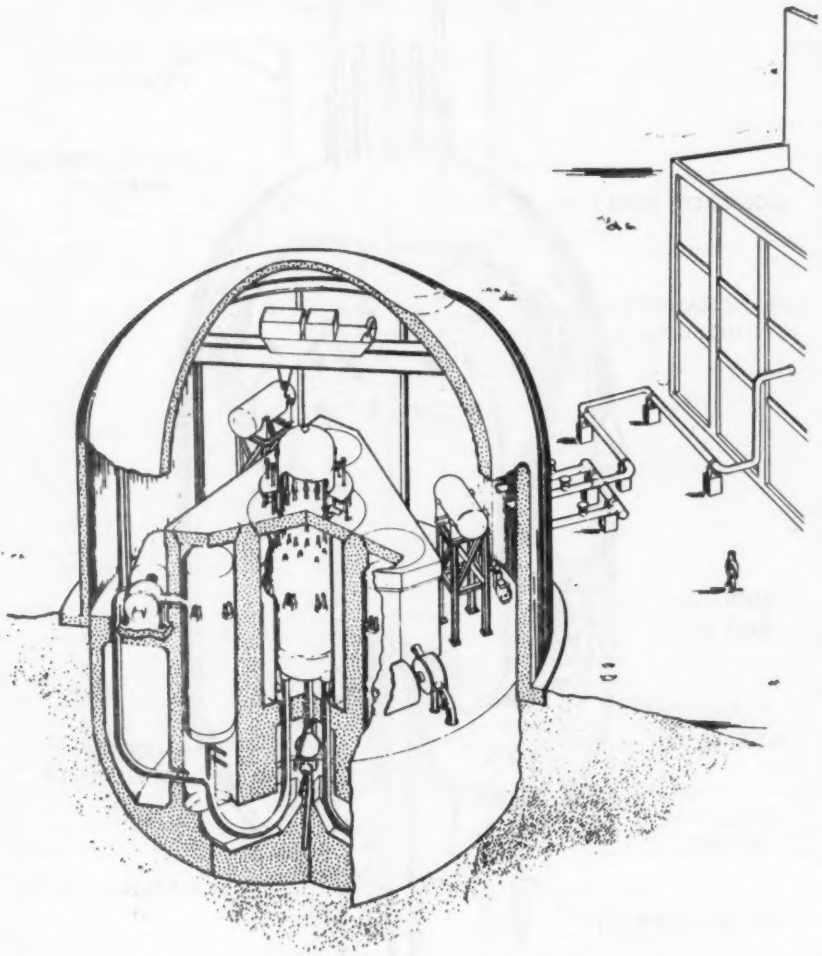

FIGURE 5.—Cutaway perspective of the primary system.

The primary loop system consists of the reactor and three compressor-steam generator loops in parallel, together with the helium cleanup and storage system consisting of charcoal adsorption beds, filters, transfer compressors, and storage cylinders. At rated output the system pressure is 965 pounds per square inch absolute and the volume of helium contained in the system is approximately 170,000 cubic feet.

The reactor and three steam generators are enclosed in a triangular concrete prism forming the biological shield. The reactor, compressors, and steam generators are mounted in a common horizontal plane shown in figure 6 and the outer walls of all vessels and pipes are exposed to low temperature gas only. Thus it is possible to design the system to provide for expansion without the use of expansion joints. Typical pipe sizes are 16 and 24 inch.

The steam generators are of the forced circulation type having an economizer, evaporator, and superheater section. Surface is provided in the form of spiral wound pancake coils joined to headers external to the generator shell. These headers are located in a shield well so that they are accessible for plugging in event of failure. Excess surface is provided in the steam generators and it is not contemplated that any repair or maintenance will be performed on them during their life other than plugging failed tubes.

The design of a once through steam generator using extended surface has also been studied and such a generator is illustrated in figure 7. This type design has the advantage of elimination of a steam drum which will ease the design requirements for the containment vessel.

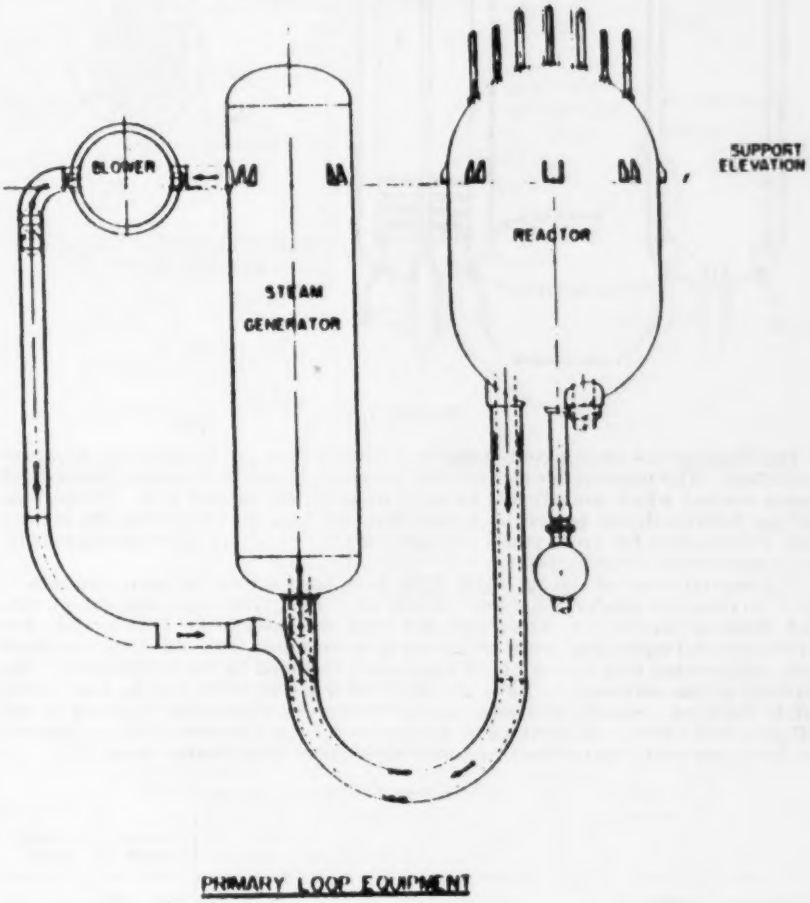

FIGURE 6.

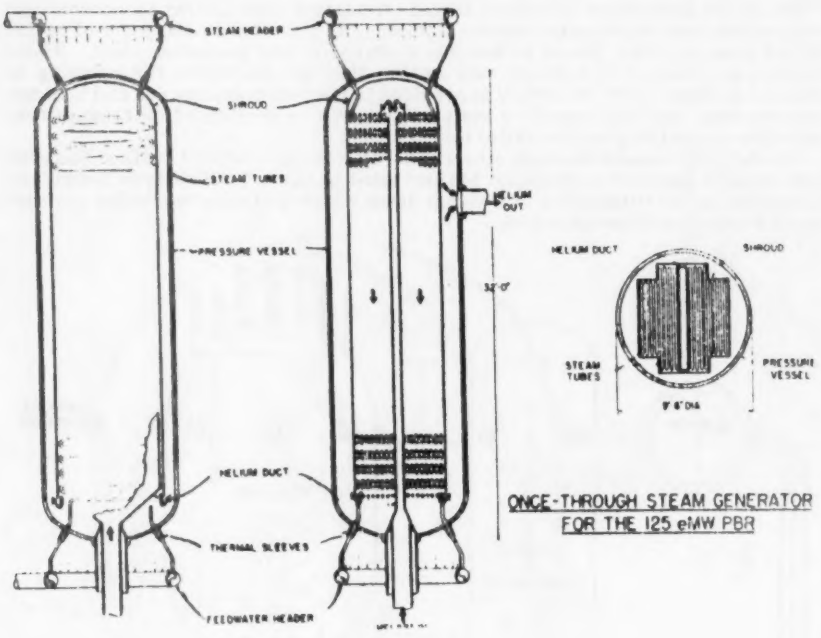

FIGURE 7.

This reactor has an inherent stability resulting from its negative temperature coefficient. The negative coefficient thus provides a basis for normal methods of power control which are effected by variations in the coolant flow. Three centrifugal blowers driven by synchronous motors are used for circulating the helium with flow control for gross power changes effected by either adjustable preswirl vanes or pressure level variations.

The capital costs of the 125 eMW-PBR have been set up in three accounts in order to establish production costs. These are; land, structures and equipment, and working capital. A direct cost for land was assumed. Direct costs for structures and equipment were estimated in accordance with standard practices with engineering and design of all equipment included in its selling price. In arriving at this estimate we have incorporated what we believe to be reasonable safety features. Should additional safety features be required an increase in the estimate will follow. In arriving at total costs for the structures and equipment, the following additions to direct cost were made, percentage being cumulative.

[Percent]

	Reactor plant	Turbine plant
Omissions and contingencies	30	5
Construction plant	15.0	
Engineering and design services	8.0	
Client's costs (including 6 percent interest during construction and 10 percent contingencies)	16.9	

NOTE.—Total, 167.5 percent of direct costs.

Working capital is assumed to be 4 percent of the total of land and structures and equipment, plus the cost of fabricating the first core and blanket loading. The capital costs are summarized in table II.

Production costs of energy from the 125 eMW–PBR are summarized in table III. Production costs are based on an annual fixed charge of 12 percent for land, 14 percent for structures and equipment, and 10 percent for working capital.

The plant is assumed to operate for 7,000 hours per year at rated output, or with an 80 percent load factor. Bulk loading of the core is assumed with a core life of 100 days, and a blanket life of 1,000 days, or 10 percent of the blanket is unloaded with each core loading. Maximum and minimum fuel costs are based on estimates received for fabricating core and blanket elements, which costs are also reflected in working capital. Fuel is assumed to be reprocessed in the AEC multipurpose plant and is priced accordingly. In establishing the reprocessing costs the thorium was assumed to be saved. Fissile and fertile material required for makeup during a core lifetime amounts to 7.68 Kg of U–233 and 70 Kg of Th. Figure 8 illustrates the minimum and maximum fuel cycle costs as determined in this analysis.

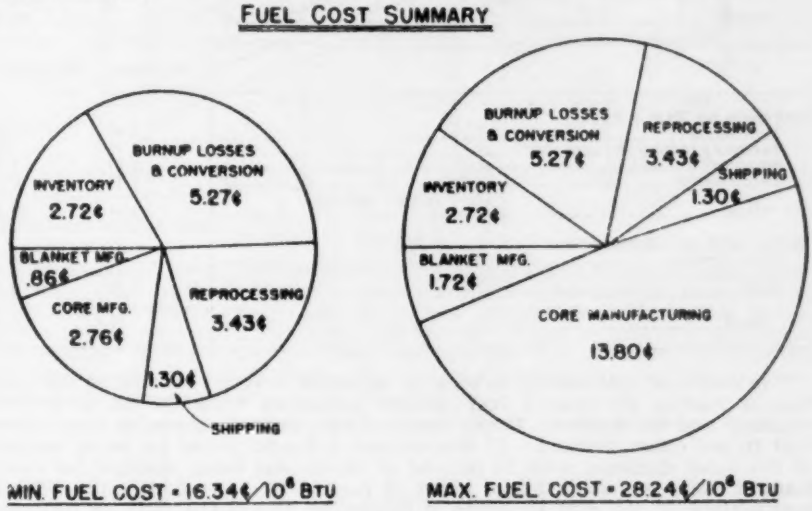

FIGURE 8.

TABLE II.—*Capital cost summary*

[In thousands of dollars]

A. Land	350
B. Structures and equipment:	
1. Structures and improvements	2,819
2. Reactor plant	8,361
3. Turbine plant	6,003
4. Accessory electrical equipment	854
5. Transmission plant	566
6. Miscellaneous powerplant equipment	287
Direct costs	18,890
7. Omissions and contingencies	2,875
8. Construction plant	3,265
9. Engineering and design services	2,000
10. Client's costs	4,570
Subtotal	31,600
Grand total	31,950
C. Working capital:	
1. General	1,275
2. Fuel element fabrication:	
Minimum	354
Maximum	966

TABLE III.—*125 electric megawatts PBR cost data*

General:	
Net capability	126,753 kilowatts.
Reactor heat output	3.12×10^{12} B. t. u.
Net station heat rate	9,077 B. t. u. per kilowatt-hour.
Load factor	80 percent.
Investment (dollars per kilowatt-hour):	
Land	$2.76
Structure and improvements	37.30
Reactor plant	110.50
Turbine plant	79.30
Accessory electrical equipment	11.30
Transmission plant	7.48
Miscellaneous powerplant equipment	3.79
Total	252.43

	Minimum	Maximum
Fuel (cents per 10^6 B. t. u.):		
Fabrication	3.62	15.52
Inventory burnup and conversion	7.99	7.99
Shipping	1.30	1.30
Reprocessing	3.43	3.43
Total	16.34	28.24
Energy (mills per kilowatt-hour):		
Fixed charges	5.13	5.20
Operation	1.00	1.00
Fuel	1.48	2.56
Total	7.61	8.76

The design of this reactor is such as to permit selective loading of the core, that is loading the central fuel channel separately from the six outer fuel channels and the blanket. Power density in the central channel is about twice that in the outer channels. If this channel is loaded twice for every loading of the outer channels, with 10 percent of the blanket being changed for every loading, there is a reduction of about 10 percent in direct fuel costs. With a modification of the core structure it is possible to achieve more or less continuous loading. The production costs resulting from this procedure are presently being studied.

In establishing the design of the 125 eMW PBR a rather complete parametric survey was made of the nuclear characteristics of this type of reactor system. This was followed by a more detailed analysis of the specific reactor core, selected from the results of this survey. The thermal power level was held constant at 350 MW, the average moderator temperature was 1,200° F. and the core height to diameter ratio was 0.9. The variable parameters considered are indicated below:

Variable:	*Range*
Wt fraction ThO_2+UO_2 in fuel elements	0.1–0.3
Average void fraction in core	.1– .39
Core diameter (feet)	7–20
Th/U atom ratio	5–50

Modified two group diffusion theory was used for the parametric survey. The model used was a homogenized, equivalent bare, cylindrical core, composed of graphite, oxygen, U–233, Th–232 and void. Since the average void fractions associated with a bed of spheres is constant at 39 percent, the voidage was varied by replacing fuel elements with solid unfueled graphite shapes which form the internal core structure.

The fast constants were determined through the use of the Fourier transform of the slowing down distribution from a point source in space utilizing 54 neutron energy groups. The Muft III computer program was used for the calculations. Hardening of the thermal neutron spectron due to the graphite moderator was included.

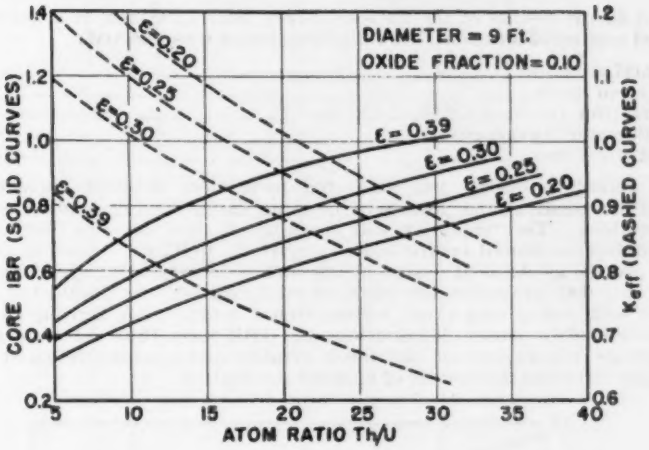

FIGURE 9.

The results of the parametric survey were expressed as K_{eff} and initial breeding ratio (IBR[1]), the latter being determined by considering the absorption of each of the 54 energy groups plus the thermal absorptions. Figure 9 is typical of the results obtained in the parametric survey. It can be seen that decreasing the voidage increases the IBR but decreases the K_{eff} at fixed Th/U ratios. Figure 10 shows the effect of core diameter on the initial breeding ratio for certain specific cases studied.

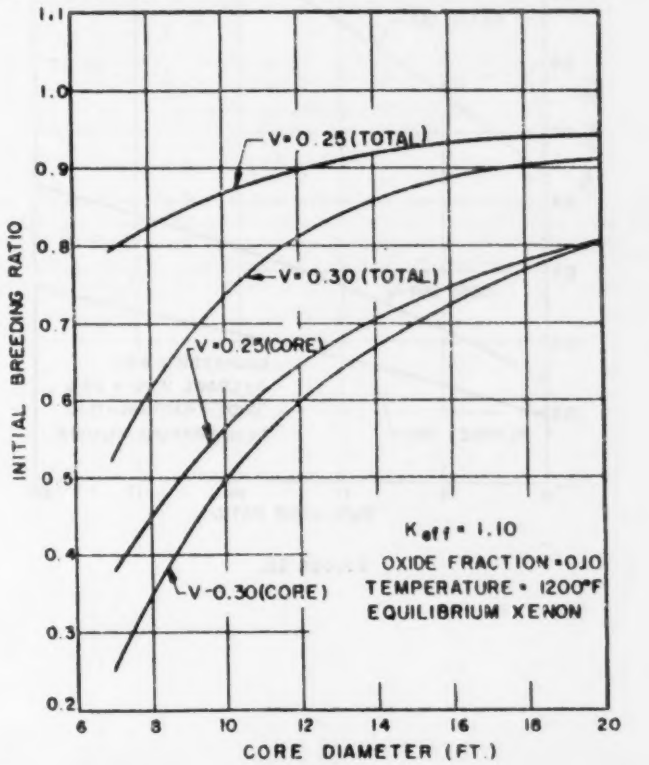

FIGURE 10.

[1] IBR is used for all cases whether values are greater or less than one.

Based on the results of the nuclear survey, fluid dynamics of a bed of spheres, and fuel cost considerations, the following design was selected:

Wt fraction oxide		0.1
Th/U atom ratio		11:1
Void fraction (average)	percent	29
Core diameter (average)	feet	9
Blanket thickness	inches	18

This reference design was subjected to a more detailed nuclear analysis. Doppler broadening and flux self-shielding factors were applied to the fast cross sections. The reactivity was reevaluated, and the core lifetime and isotope buildup calculated on the basis of uniform buildup. Since by this time a rather precise mechanical design of the core, core-supporting structure, pressure vessel, etc., was available, the physical configuration was duplicated insofar as possible with radial and axial, 1-dimensional, multiregion, 2-group calculations. The neutron flux, power distribution, and IBR were thus determined. Figure 11 indicates the results of the more detailed calculations referred to above, and figure 12 shows the results of burnout calculation.

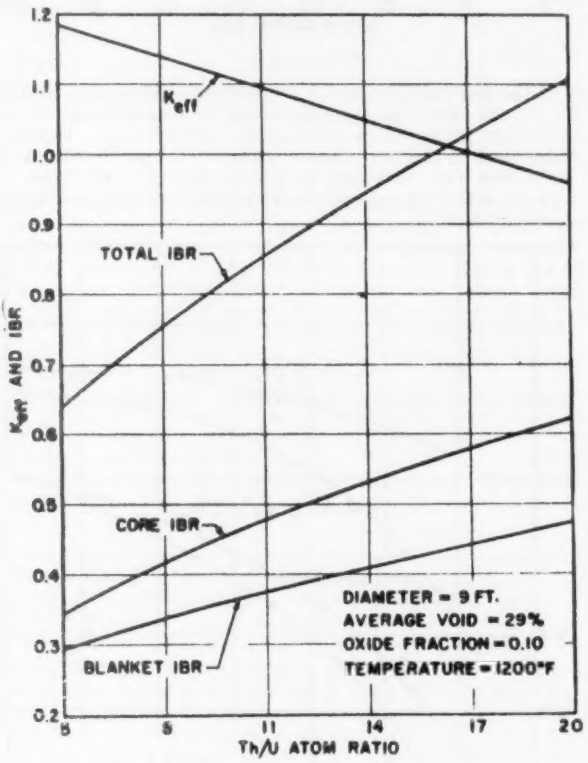

FIGURE 11.

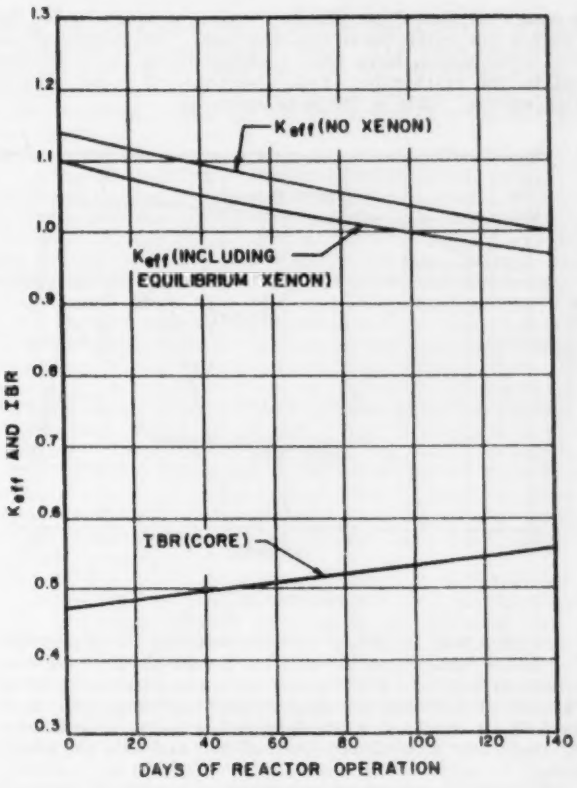

FIGURE 12.

Since the values of α for U–233 developed in connection with this project were generally higher in the epithermal region than those used by others, and since approximately 40 percent of the fissions in this reactor are epithermal fissions, the core-breeding ratio was profoundly affected. Listed below is a comparison of the overall effect of using one or other of these two sets of α values.

	Alco	ORNL
α (flux weighted average)	0.257	0.1433
Atoms fissioned	100	100
Atoms U–234 formed	25.7	14.33
Total atoms U–233 lost	125.7	114.33
Conversion ratio	0.846	1.041
Atoms Th converted	106.2	119.1
Net change, U–233 atoms	−19.5	+4.8

It can be seen that, based on ORNL α values, a batch-loaded breeder reactor is possible with a net reduction in the fuel cost. The results of recent measurements at the MTR, which have been reported to us by C. Prescott, or ORNL, indicate that in the epithermal range the value of α falls between Alco and present ORNL values. This is shown in figure 13.

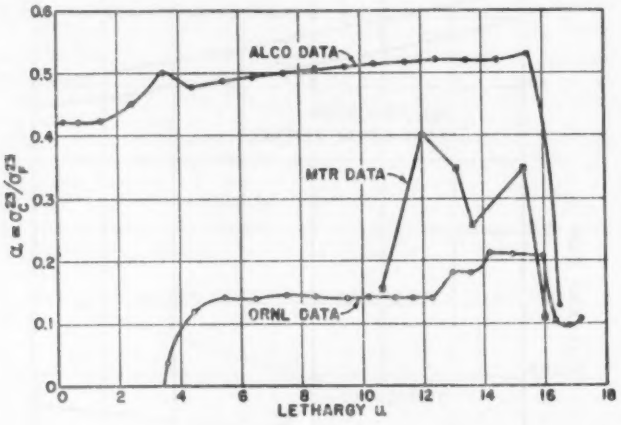

FIGURE 13.

Study of figures 9 and 10 indicates that breeding in this system is possible. The IBR of a batch-loaded reactor can be increased by decreasing the voidage with an increase in Th/U to hold K_{eff} constant and by an increase in diameter. Taking advantage of the decrease in parasitic capture resulting from Xe leakage will also help in reaching a batch-loaded breeder. Additional calculations are presently underway to evaluate these effects and also the effect of the latest MTR α values.

Since the IBR and K_{eff} bear an inverse relationship to each other, it seems apparent that a breeder can also be had (based on Alco α values) by dropping the K_{eff} to slightly in excess of 1.0. Obviously, such a reactor would have a very short lifetime before reactivity loss required shutdown. Since the PBR fuel concept is amenable to partial refueling, a continuously refueled core of low initial K_{eff} and high IBR should afford the economic and logistic advantages associated with a breeder. The physics and economics of such a core are presently under study.

We have just begun an investigation of the possibilities of a plutonium recycle version of the pebble-bed reactor. This fuel cycle, as in the case of the thorium cycle, has the obvious advantage of releasing the operator from dependence on a separation plant for the supply of fissile material.

The pebble-bed reactor system was selected after study of a number of configurations of graphite-uranium reactor types. The basic advantages this system offers are that the ceramic fuel elements are in compression; the system can be loaded and unloaded by relatively simple fluid-handling techniques; and the spherical fuel element is amenable to a variety of compositions and mass-production techniques.

Three questions arise when considering the use of spherical fuel elements in a static bed: i. e. the self-welding of the balls, which would prevent discharging the bed, the ability of the bed to accommodate thermal growth without rupturing the containing wall, and the ability of the balls to withstand impact stresses during reactor loading operations. Self-welding of unclad graphite balls at PBR operating conditions is impossible since the temperatures and pressures required to weld graphite are of the order of 50,000 pounds per square inch and 5000° F., which is well above the PBR operating temperature and pressure. Limited work on the self-welding characteristics of metal carbide coatings indicates that they too are acceptable as long as the free metal in the cermet is kept to a minimum. Geometric considerations indicate that the randomly packed bed can accommodate itself to thermal growth. The packing fraction of spheres in their closest orientations is 84 percent while the packing fraction of a randomly packed bed is only 61 percent. That is to say a randomly packed bed contains "holes." Since the top surface of the bed is unrestricted, thermal growth causes an upwards displacement of the misalined balls in a randomly packed bed, thus relieving the radial forces. The concern over free fall during loading has been alleviated by impact tests on a reasonably large sample of fueled specimens. These tests indicate that free falls of the order of 75 to 100 feet result in no ball damage.

Fuel elements of this type can be manufactured in a variety of ways. For example, both oxides can be added simultaneously to a porous graphite ball by impregnation in a nitrate solution followed by dehydration and denitration. Alternately, the thoria can be blended with the graphite during the preparation of the ball and the urania added later by impregnation. Another procedure involves addition of both urania and thoria at the time of preparation of the ball. This would be done by blending suitably sized particles of UO_2, ThO_2, graphite, and binder—all in the proper proportions—and molding the ball, followed by curing of the binder. Yet another procedure involves concentrating the urania and possibly the thoria in a relatively small lump in the center of an otherwise graphite ball. Each of these main variants are subject to still other minor variants. Finally each type may or may not be clad with a ceramic-type cladding such as silicon carbide. Typical fuel balls manufactured by these methods are illustrated in figure 14.

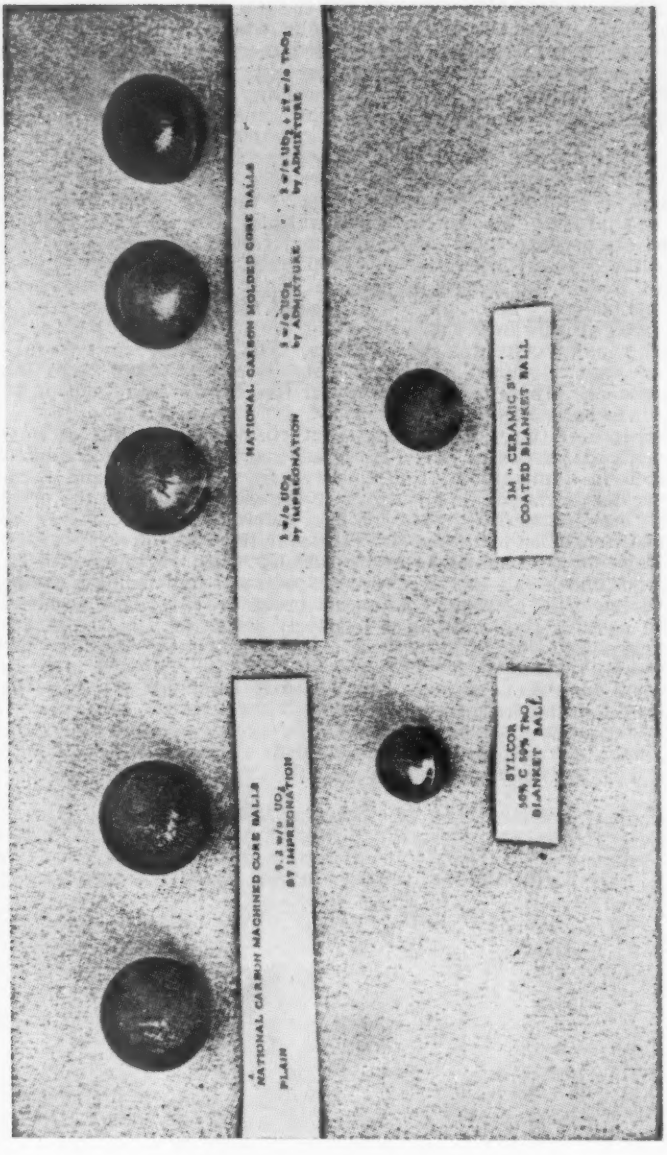
NATIONAL CARBON MACHINED CORE BALLS
PLAIN
3 w/o UO2
BY IMPREGNATION
NATIONAL CARBON MOLDED CORE BALLS
3 w/o UO2
BY IMPREGNATION
3 w/o UO2
by ARMATURE
3 w/o UO2 + 15 w/o ThO2
by ARMATURE
SYLCOR
54% C 46% ThO2
BLANKET BALL
3M "CERAMIC 5"
COATED BLANKET BALL

FIGURE 14.

Figure 15 presents an appraisal of the relative advantages of manufacture by each of these three methods, with respect to certain significant characteristics. It must be stressed that these relative standings are only opinions and remain to be confirmed by work presently underway.

There are two basic issues that must be resolved in order to determine the best type of fuel element for the pebble bed reactor. First is the question of whether a simple unclad fuel element which offers the possibility of minimum manufacturing and reprocessing cost will perform satisfactorily under irradiation. That is, will the simple fuel element retain its structural integrity and will the fission product leakage rate be acceptable? Second is the question of whether or not there are coatings that will reduce fission product leakage and yet have favorable structural and economic characteristics.

Relative Advantages of Fuel Element Manufacturing Methods

TYPE	IMPREGNATED	ADMIXTURE	LUMPED
Retention of fission products	3	2	1
Structural integrity under irradiation	3	2	1
% weight fissile material	3	2	1
Mechanical strength	1	2	1
Development of manufacturing technique	2	1	3
Economy of manufacture	1	2	3
Ease of remote fabrication	1	2	2

FIGURE 15.

During reactor operation, volatile fission products will diffuse from the fuel elements and circulate with the gas stream. The quantity of fission products which are released will depend on the method of manufacture of the fuel element and on the temperature of the reactor core. Use of a ceramic coating will facilitate the retention of fission products within the fuel element; however, the performance of such coatings is as yet unproven. It has been assumed, therefore, that all of the fission products volatile below 2,500° F. will be released to the gas stream. This assumption affords a conservative basis for the primary system shield design. This assumption is quite conservative for three reasons:

1. Only the fuel element center temperature ever reaches 2,500° F.
2. Only part of the fuel elements are in the hot zone in the reactor. Fully 98 percent of the fuel elements will have surface temperatures significantly below 2,000° F.
3. Some of the gaseous fission products have such short half lives that it is improbable that they could diffuse out of the fuel element before they decay to nonvolatile daughters.

Reprocessing of graphite-uranium fuel elements differs from that of metal clad and metal matrix elements insofar as the head end treatment is concerned. Costly acid dissolution steps with the resulting large volumes of waste liquors to be disposed of are eliminated. The head end treatment consists of crushing to expose the uranium to nitric acid or incineration of the graphite followed by solution of the ash in nitric acid. Once in solution, the uranium can be subjected to a modified thorex extraction operation to separate the fission products. Since the fuel element lends itself to remote manufacturing techniques, a high level of decontamination is not believed to be necessary. The combination of the simple head end treatment and the low decontamination factor should result in significant savings in reprocessing costs.

The basic research and development program for this reactor concept covers three general areas, exclusive of component development, both preceding and paralleling the design, construction and operation of an experimental reactor. These areas are fuel cycle development, fission product technology, and pebble bed technology. Although graphite-uranium is an old fuel concept, it has never been pursued with the thoroughness applied to others. Its development would include fabrication techniques, with emphasis on remote operation, fuel element stability under reactor operating conditions, and the development of head end reprocessing techniques. Fission product technology would include determination of the quality and species of fission products released from the fuel elements selected for their use, the nature of their deposition in a primary loop, methods for their continuous removal and methods of decontaminating and maintaining the primary loop equipment. Pebble bed technology would cover the fluid dynamics and heat transfer characteristics of a design bed together with the mechanics of ball manipulation.

A limited amount of work has and is being done on the fuel cycle and the pebble bed. Impregnated, admixtured and lumped fuel elements, both clad and unclad, have been obtained or are being developed by both industry and research organizations. A fuel irradiation program is in progress at the Battelle Memorial Institute where unclad elements, made by the three methods mentioned, will be irradiated in a static capsule. By replacing the thorium of the 125 electric megawatt PBR core element with fully enriched uranium and exposing the specimen in a 10^{13} flux for 6 weeks, about half the fissions that would occur in the average ball of the reference design can be produced in the specimen. Figure 16 illustrates a preliminary design of the capsule which is capable of holding three pairs of specimens of different types. Critical temperatures are measured by embedded thermocouples. The design element temperature is 1,500° F., controlled by heat flow through the graphite blocks containing the specimens, through the capsule wall and through fins to the outer sheath to the water in the BRR.

The primary purpose of these tests is to determine the change from preirradiation to postirradiation values of such properties as compressive strength, impact strength and surface abrasion resistance. Additional tests will include weight changes, dimensional stability, uranium migration and loss and fission product leakage.

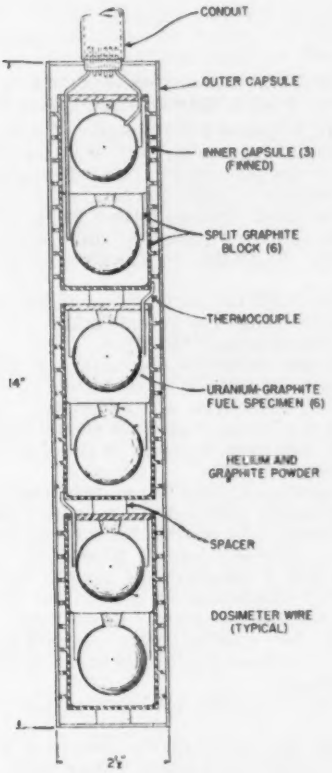

FIGURE 16.

Pebble-bed fluid flow and heat-transfer characteristics have been well documented on a laboratory scale at low Reynolds numbers. However, these data are based on average values and do not show the effect of variation in radial voidage due to wall effects. This is important in the 125 electric megawatt PBR due to flux peaking at the graphite wall. An experimental method of determining this radial variation in voidage has been established and work is in progress to determine this variation over a wide range of ball to cylinder diameter ratios.

The pebble-bed reactor concept described in this paper can be classified as an advanced high-temperature reactor. The uranium-graphite fuel system, on which the PBR is based, has long been recognized as a potential high-temperature fuel system, but it has not been as vigorously pursued as others. We believe that the spherically shaped fuel element offers a unique solution to the fabrication and handling problems of the uranium-graphite system and that a thorough development is warranted at this time.

SARGENT & LUNDY,
Chicago, Ill., October 30, 1958.

Mr. JAMES T. RAMEY,
Executive Director, Joint Committee on Atomic Energy,
Congress of the United States, Washington, D. C.

DEAR MR. RAMEY: In response to your letter of August 21, 1958, we are pleased to have the opportunity of expressing our views on the questions set out in this letter as they relate to the proposed expanded civilian nuclear-power program. From the date of November 1, 1958, set for replies, we assumed that the Joint Committee intended to allow sufficient time for a study and understanding of the report covering the proposed program, and we have taken advantage of this period for that purpose. In giving our answers, we have, for convenience, stated the question.

(1) Do you agree with the three major objectives (p. 4) of the program? If not, what changes would you recommend?

We agree with the program objectives.

(2) Are the general technical objectives (p. 5) adequate? If not, what additions or deletions would you recommend?

The general technical objectives are adequate. Achievement of success or partial success in several of these objectives should lead to significant cost reductions. We would like, however, to suggest the following additional objectives that have to do with lowering costs:

(*a*) *Safety requirements.*—Critically review those costs, both capital and operating, that are primarily attributable to safety aspects, with the objective of reducing them consistent with practical minimum safety requirements.

(*b*) *Simplification of reactor licensing procedure.*—The work involved, starting with preparation for a construction permit to granting of an operating license, represents many thousands of dollars for almost any reactor project.

(*c*) *Personnel training and licensing.*—Lower costs of personnel training and licensing of personnel for nuclear plant operations by critically reviewing present procedures. These costs are in the order of several dollars per kilowatt of installed electric capacity.

(3) Please comment on the adequacy of the scope of the technological program (p. 6).

We would agree that the technological program is broad in its scope. We further believe that competitive nuclear power may only be achieved through sharp reductions in both the fuel cycle costs and the capital costs, which appear to be objectives of the technological program. To point up the necessity of sharp reductions in capital costs, each $100 of excess cost per kilowatt of a nuclear plant over an equivalent conventional plant represents 2 mills per kilowatt-hour based upon 14 percent capital charges and 7,000 hours per year use (about 80 percent capacity factor). The excess capital costs of nuclear plants over equivalent conventional plants at the present development of nuclear technology are substantial.

(4) In your opinion, is the proposed list of reactors in table I the best list for this program? If not, what changes would you recommend?

The 21 reactor concepts listed in table I cover a wide range of reactor types, and the carrying out of such a program should add materially to reactor technology. However, it raises the question as to how effective this program might be in achieving competitive nuclear power in the time period allowed, as it appears that many of these reactors are developmental or first-generation types. While recognizing the advantages of such a broad program in increasing nuclear technology, it is urged that certain of the more promising types, such as the so-called water reactors, be exploited into a series of progressive projects with each succeeding one incorporating the knowledge and experience gained from its predecessor. For example, there is agreement on the desirability of obtaining increased power density to reduce capital costs and of obtaining nuclear superheated steam to increase efficiency. We believe the best procedure for these items would be two separate experimental reactors of the same general type or concept designed specifically to give data and experience on each phase. Later, such improvements might be incorporated into the same core of an advanced reactor design of that same type to carry out a progressive program.

(5) Do you consider the cost estimates (p. 8) to be reasonable? If not, please point out the areas with which you disagree.

The average of $875 per KW (e) for plants constructed ($500 per kilowatt construction plus $250 per kilowatt associated design and development plus $125

per kilowatt resulting from plants designed but not constructed) appears to be an adequate estimate and is as good, no doubt, as can be substantiated at this time. The costs could be lowered if too much of the effort is not allocated to reactor types for which technology is not as fully developed as in the so-called water types. For example, it should be recognized that the homogeneous, sodium-cooled breeder type, fused salt-fuelel, liquid-metal-cooled, and gas-cooled graphite moderated types are apt to be high capital cost plants at the present stage of reactor technology applicable to such types.

(6) What is your opinion of the policy on organization and administration proposed on page 9? Will they adequately implement the positive leadership required for success of the program?

The organization and administration program as outlined in the report of the proposed expanded civilian nuclear power program is clearly stated and logically arranged. However, because of the present substantial excess cost of nuclear power over conventional power, it would appear that there would not be too much incentive to proceed with reactor projects on the privately owned plant basis where a major portion of the excess cost is absorbed by the private utility involved, as compared with the Government-owned plant basis where the Government assumes the excess cost. For further discussion on this phase of the program, see answer to question 7.

The outline of assistance to projects in other countries would appear to be adequate. It is assumed that in rendering this assistance to other countries, every effort would be made to have the experience gained in the development of nuclear power translated to or be made available to our domestic program, and further that American manufacturers, architect-engineers, etc., would participate to the fullest practical extent in the program.

(7) If it should later prove necessary, what other types and amounts of assistance would you recommend for the domestic program? For the foreign program?

If it is the desire of the Joint Committee and the Atomic Energy Commission, in carrying out their proposed expanded civilian nuclear-power program, to encourage the installation of privately owned plants, it is doubtful as pointed out in the answer to question 6 that adequate incentives have been provided for that purpose in the program as now set up. It is our belief that additional amounts and types of assistance will be required to insure meeting the objectives of the domestic program as it relates to privately owned plants. This subject is discussed in the last paragraph of page 12 of the report. Some of the considerations which lead us to believe that this additional assistance would be required are:

(*a*) Generating capacity represents a major capital cost and operating cost for a utility system. It is acknowledged that presently, nuclear power is not competitive with conventional power either as to capital costs or fuel cycle costs, and it is doubtful also whether other operation and maintenance costs are on a parity. The excess of nuclear-power costs over conventional power is substantial. For example, taking as an average 7 mills per kilowatt-hour as the overall cost of conventional power, nuclear-power costs for the immediate future may range from 2 to 3 times or more.

(*b*) Aside from the newness of the nuclear-power activities and the lack of extended experience in the design, construction, and operation of full-scale plants which are contributary to higher costs, there are certain inherent characteristics with respect to the utilization of nuclear power which will tend for some time to result in higher costs. These have to do with the radiological and biological aspects of nuclear energy with their attendant safety problems. Present methods of coping with these problems result in heavy capital expenditures for shielding, containment vessels, large site areas, fuel handling, cleanup systems, waste storage, and many corollary items. These items also result in increased operating costs, particularly as they necessitate providing personnel for operation and health and safety protection substantially beyond that for conventional plants. Special training requirements of the total plant personnel and licensing of certain personnel can also be classified as an excess cost as compared to conventional plants.

(*c*) Nuclear plants built in the immediate future will quickly reach obsolescence with respect to nuclear plants achieving competitive power. A plan for dealing with this obsolescence could act toward offsetting excess costs.

(*d*) The regulation of private utilities by State and/or Federal agencies is such that while commissions recognize the prudence of spending reasonable

amounts of money for research and development, it is doubtful that the large differences in excess costs between conventional power and nuclear power could be underwritten on a continuing basis for any extended nuclear power development program. There is, of course, the possibility of distributing this excess cost among a utility group formed to cover a specific reactor development program. However, a casual survey of the present situation indicates that it would be difficult to form many additional utility groups beyond those already formed.

(*e*) As a measure of the magnitude of excess costs, a nuclear plant of 100 MW (e) capacity operating at 80 percent capacity factor with an excess cost of 7 mills per kilowatt-hour would entail an excess cost of approximately $5 million per year, which over the operating life of the plant could exceed its original cost.

In order to implement the proposed expanded civilian nuclear power program and particularly to encourage privately owned plants, in addition to the assistance suggested by the Joint Committee such as waiver of use charges on nuclear materials, loan of heavy water without charge, work at AEC laboratories, and other research and development work, consideration should be given to making outright grants to absorb a major portion of the excess costs associated with nuclear power. This additional assistance could take several forms, examples of which are given:

(*f*) Outright grants to absorb a major portion of the excess capital costs, plus such assistance as may be required to more nearly equalize fuel cycle costs and other operating and maintenance costs. This latter assistance could take the form of the Commission providing for the first core (which is generally experimental) and making such adjustments in reprocessing charges that would be necessary. In other words, the assistance on both capital charges and operating costs should be such that the privately owned plants would be reasonably comparable with the setup for Government-owned plants. It should be pointed out that the owners of privately owned plants should be expected to pay capital costs equal to an equivalent conventional plant and also should be willing to underwrite some portion of the excess costs in furtherance of developing a nuclear civilian power program.

Further, such payments accruing from the privately owned plants would reduce by that amount the Government's cost, resulting in less cost for such an arrangement than the program for Government-owned plants while obtaining comparable results in terms of nuclear technology and know-how.

We believe this general plan is adaptable to a wide range of reactor projects, particularly those in table I which involve new technology and development. The stated objective of fortify the position of leadership of the United States in the eyes of the world in the peaceful applications of atomic energy, particularly with regard to power, could be achieved under the above type of plan.

(*g*) Another one of the program objectives has been stated as achieve and demonstrate in the United States nuclear power competitive in cost per kilowatt-hour by 1970.

We believe the surest way to attain this objective is to concentrate development on a reactor concept which has demonstrated technical feasibility, has proven safety requirements, and has sufficient technology behind it to insure reasonable expectancy of achieving competitive nuclear power. We believe the so-called water reactors meet these qualifications.

In order to expedite the above objective and at the same time compensate for the excess costs that will be involved in carrying out such a program, we urge that consideration be given to a plan whereby—

(g–1) The utility or utility group, private or public, would underwrite the investment portion of the project and would own and operate the completed facility.

(g–2) The Government (AEC) would underwrite or furnish without charge all fuel cycle requirements including core fabrication, inventory, reprocessing, etc., for a period not to exceed 10 years, with provision for reevaluation of the economics as indicated below. All spent fuel, including plutonium and any other byproducts, would be the property of the Government. The AEC would also underwrite without charge the necessary research and development work for the particular approved project.

(g–3) The economic reevaluation would be on the basis that the Government contributions are intended to offset all or a major portion of the excess cost of nuclear power over an agreed upon target cost for conventional power.

The costs would be subject to periodic review and adjustments made in the contributions accordingly.

(g–4) An approved project would be one submitted by a utility and accepted by the AEC or one sponsored by the AEC and accepted by a utility.

We believe that the merits of this plan are: first, there is a clear-cut division of responsibilities with each respective party having responsibility for those items it more or less controls. The AEC is in control of fuel resources and the development, operation, and allocation of nuclear fuel production facilities for defense and peaceful uses; also, reprocessing facilities and facilities for research and development. It is logical under this plan for the utility to be responsible for the capital cost of the project it undertakes to design, construct, operate, and will own.

Second, there would be a direct incentive for the utility paying the bill to achieve the lowest possible capital costs. This would be implemented through the channels of competitive bidding with the ingenuity of free enterprise brought to bear.

Third, the concentration on one class of reactors should reduce fuel costs due to standardization, repetitive orders, and volume.

Finally, the objective of competitive nuclear power would be achieved with minimum cost and minimum time by concentrating the resources of the Government and American industry on this objective.

Yours very truly,

SARGENT & LUNDY,
By ALF KOLFLAT.

UNITED ENGINEERS & CONSTRUCTORS, INC.,
Philadelphia, Pa., October 13, 1958.

Mr. JAMES T. RAMEY,
Executive Director,
Joint Committee on Atomic Energy,
Congress of the United States of America,
Washington, D. C.

DEAR MR. RAMEY: We reply to your communication of August 21 requesting our comments and views on the proposed expanded civilian nuclear reactor program. Specifically we reply to the seven questions in your letter as follows:

1. Major objectives

We most heartily approve of the objectives as outlined.

2. Technical objectives

The outline appears logical; we might suggest the addition of low-cost processes for manufacturing low-enrichment fuels.

3. Technical program

The technical program as described is adequate; we might add that the high-cost fuel areas in the United States should be placed in the first category.

4. List of proposed reactors

We are of the opinion that the list presented should cover all requirements, particularly as qualified in paragraph 5 on page 8 of the program.

5. Cost estimates

We believe that the cost estimate of $500 per kilowatt is as conservative as can be considered at the present time.

6. Organization and administration program

We believe that the policies as outlined are a necessary requirement. Greater stress should be placed on the encouragement to public utilities.

7. Suggested other assistance

We would strongly recommend consideration to financial assistance be given to encourage the program's adoption by public utilities in the form of the cost differences between nuclear and conventional plants.

The adoption of the program is strongly recommended with greater encouragement extended to public utilities.

Sincerely yours,

A. G. MIDDLETON, *Vice President.*

APPENDIX 6

TABULAR SUMMARY OF REPLIES TO JCAE LETTER OF AUGUST 22, 1958

This table is designed as a handy guide and reference to industry's replies to the questions of the Joint Committee.

It is not meant to represent the complete views of any one company since some answers were several paragraphs long and have necessarily been condensed into a few words in the table. The complete views are available in the texts of the replies printed in appendices one through five. (Page numbers refer to Joint Committee print of August 1958.)

EQUIPMENT COMPANIES

Name of company	1. Do you agree with the 3 major objectives (p. 4) of the program? If not, what changes would you recommend?	2. Are the general technical objectives (p. 5) adequate? If not, what additions or deletions would you recommend?	3. Please comment on the adequacy of the scope of the technological program (p. 6).	4. In your opinion, is the proposed list of reactors in table I the best list for this program? If not, what changes would you recommend?	5. Do you consider the cost estimates (p. 8) to be reasonable? If not, please point out the areas in which you disagree.	6. What is your opinion of the policies on organization and administration proposed on p. 9? Will they adequately implement the positive leadership required for success of the program?	7. If it should later prove necessary, what other types and amounts of assistance would you recommend for the domestic program? For the foreign program?	Additional remarks
Alco Products, Inc, by Kenneth Kasschau, manager of engineering.	Yes. Goal of 1970 may be optimistic. Basic assumption as to rate of fossil fuel energy consumption for all purposes needs careful consideration.	Adequate. Technical objectives of more concern to executing agency than to Congress but understanding by Congress can encourage proper atmosphere.	----------	List of reactors needs careful review by technically competent engineering and scientific group. Many concepts listed suffer with severe limitations.	Estimates appear adequate.	Support AEC responsibility for research and development continuing through small plants. Don't support construction of large plants and pressure on AEC to proceed even in absence of satisfactory industrial proposal.	----------	
Allis-Chalmers Manufacturing Co. by R. M. Casper, manager, nuclear power division.	Agree----------	Adequate---------	Adequate. Maintain program flexible.	A list is desirable. Difficult to state list given is best. Reappraisal is essential.	Appear reasonable. Must be flexible.	Agree AEC must be responsible. Assistance to industry should not be restricted to list. More	Believe more liberal interpretation of research and development work and assistance to in-	

						liberal consideration of time allowed industry to submit proposals, etc., required.	dustry in construction and operation should be considered.	
Atomics International, a division of North American Aviation, Inc., by C. Starr, vice president.	do	do	Adequate	Believe that organic-cooled reactor in table I should be changed from 50 to 150 megawatts.	Reasonable	Satisfactory		
Babcock & Wilcox Co. by Alfred Iddles.	Proper and adequate. If it were not for international political situation more leisurely course than 1970 goal could be followed in view of abundance of fossil fuel in the United States.	do	Adequate. Emphasize wherever feasible building prototype rather than large plants.	Adequate	Good as possible. Less large reactors will decrease cost.	Agree with AEC program responsibility. AEC should not have dictatorial powers in its relation to industry. Don't construct large plant unless prototype gives reasonable promise of success.	Greater flexibility needed by AEC in granting industry assistance.	Comments submitted as individual not as officer of company.
Borg-Warner Corp., by J. F. Weiffenbach, director, research and engineering.	Agree. Goals difficult to achieve in time specified.	do	Adequate	Generally satisfactory. Consider building smaller plants.	Appear reasonable. Inadequate if industry does not support.	Suggest rewording to increase industry participation.	Consider use of independent study and analysis of operating and maintenance experience to guide action.	
General Electric Co., by F. K. McCune, vice president and general manager, atomic products division.	Sound and attainable.	Objectives are desirable. Would be desirable if AEC periodically stated its specific objectives and mechanics established for receiving views of industry.		Suggest that better, faster, and cheaper results would be obtained if smaller number of promising types were concentrated on in construction phase.	If the large range of reactors in the report are explored through several generations the $875,000,000 estimate will be exceeded.	Better results will be obtained if reactor types are selected by independent risk-taking groups rather than on centralized basis.	Government aid rather than Government ownership will lead to faster progress and, if equitably provided will reduce public-private controversy and reduce fear of long-term role of Government on power industry.	

TABULAR SUMMARY OF REPLIES TO JCAE LETTER OF AUGUST 22, 1958—Continued

EQUIPMENT COMPANIES—Continued

Name of company	1. Do you agree with the 3 major objectives (p. 4) of the program? If not, what changes would you recommend?	2. Are the general technical objectives (p. 5) adequate? If not, what additions or deletions would you recommend?	3. Please comment on the adequacy of the scope of the technological program (p. 6).	4. In your opinion, is the proposed list of reactors in table I the best list for this program? If not, what changes would you recommend?	5. Do you consider the cost estimates (p. 8) to be reasonable? If not, please point out the areas in which you disagree.	6. What is your opinion of the policies on organization and administration proposed on p. 9? Will they adequately implement the positive leadership required for success of the program?	7. If it should later prove necessary, what other types and amounts of assistance would you recommend for the domestic program? For the foreign program?	Additional remarks
Nuclear Metals, Inc., by Albert R. Kaufmann, vice president and technical director.	----------	----------	----------	Reactor types should contain statement of proposed fuel element required for successful performance.	----------	----------	----------	In general, program sounds good.
Nuclear Products-ERCO, division of ACF Industries, by H. Etherington, vice president.	Agree. Believe there is more than 2-year differential between foreign and United States—suggest 1965 for foreign competitive cost goal.	Suggest addition of safety requirements analysis.	Agree----------	Process heat reactor describes a purpose not type. Not clear why steam-cooled heavy water moderated is listed. Favor decreased size reactors.	Reasonable----------	Policies are good with exception that AEC not build large reactors unless necessary technical data cannot be obtained from small reactor.	Third party liability is major problem with foreign reactors.	
Raytheon Manufacturing Co., by T. H. Johnson, vice president.	Substantial agreement.	----------	----------	----------	----------	----------	----------	
Sylvania-Corning Nuclear Corp., by Lee L. Davenport, president.	Objectives are clear and unobjectionable. Suggest adding that objectives be achieved in manner consistent with our free-enterprise	Yes----------	----------	Troubled by suggestion of specific list of reactors. Seems to be inconsistent with free-enterprise system.	Troubled by proposed organization and administration. Seems inconsistent with free-enterprise system.	----------	Provide economic incentives for private enterprise by statutory provision to permit rapid depreciation and additional	

	free-enterprise system.						tax incentives to make up cost difference of nuclear plants.
Westinghouse Electric Corp., by Charles H. Weaver, vice president.	Recommend placing objective of fortifying United States position of leadership first and deleting "in eyes of world." Specify competitive in high United States fuel cost areas.	Adequate. Tie development program to specific goals which relate to tangible reactor project objectives.	Well thought out.	More than adequate. Redetermine as work progresses.	Reasonable.....	Organization and administration outlined is desirable for at least few years. Can only be achieved through adequate technical staffing of AEC. Fully exploit initiative of private enterprise.	Certain that additional assistance will be necessary later. Suggested revisions of secs. 44 and 169 of act highly desirable.
REACTOR EXPERTS							
Greninger, A. B., acting general manager, General Electric Co., Hanford atomic products operation.	Spell out objectives more precisely. Don't believe outlined program attain 1970 United States objective.	No serious objections. Some items are more important then others, e. g., breeding per se is of no importance in developing economic power at early date although it does deserve some research and development attention.	-----	Limit Government reactors to experimental and prototypes. Power reactors should be selected by industry. Believe concentration on few types is necessary.	Reasonable.....	Don't agree with centralized direction and Government construction of full-scale reactors.	Best way to stimulate progress is capital subsidy and Government research and development support.

TABULAR SUMMARY OF REPLIES TO JCAE LETTER OF AUGUST 22, 1958—Continued

REACTOR EXPERTS—Continued

Name of company	1. Do you agree with the 3 major objectives (p. 4) of the program? If not, what changes would you recommend?	2. Are the general technical objectives (p. 5) adequate? If not, what additions or deletions would you recommend?	3. Please comment on the adequacy of the scope of the technological program (p. 6).	4. In your opinion, is the proposed list of reactors in table I the best list for this program? If not, what changes would you recommend?	5. Do you consider the cost estimates (p. 8) to be reasonable? If not, please point out the areas in which you disagree.	6. What is your opinion of the policies on organization and administration proposed on p. 9? Will they adequately implement the positive leadership required for success of the program?	7. If it should later prove necessary, what other types and amounts of assistance would you recommend for the domestic program? For the foreign program?	Additional remarks
Hilberry, Norman, director, Argonne National Laboratory.	Generally agree...	In longer range program place major effort and priority on breeding program.	.....	.....	.....	Transfer responsibility for development of well-proven reactor types to industry.	Give industry whatever support turns out to be needed in development of well-proven reactor types.	Nuclear reactors for generation of electrical energy may not provide the major long-range contribution to mankind. Reactors supplying ultra-high temperatures and radiation fluxes may be of greater significance then for electrical energy generation. Basic research and development in this area should be started immediately.
Powers, Philip N., president, Internuclear Co.	Consider fortification of United States position primary objective of importance—others	Excellent.....	Excellent.....	Hope that organic-cooled reactor includes concept using heavy water moderator.	Reasonable.....	Adequate. AEC should make sure industry is consulted on meaning of reasonableness	Include assurance on price and availability of enriched uranium for foreign projects.	

Simpson, J. W., vice president and general manager, Bettis atomic power division, Westinghouse Electric Corp.	are purely arbitrary and clutter up the picture.							
Weil, Dr. George L.	It's assumed that 1968 date is based on best judgment of foreign nations. Little in economy of United States conventional fuel resources indicates the implied urgency of 1970 date. 2-year interval between foreign and United States is relatively short. Appears that statement of priority is necessary since objectives may not be consistent. Question necessity of Government underwriting extensive nuclear industry in United States—couldn't money be spent in other item of national interest, e. g., schools?	Once national objectives are established AEC should assume technical leadership for determining program.			Positive leadership must be supplied by AEC—from DRD and staff. Believe it desirable for JCAE to include in proposed program strong positive support of DRD authority, staffing, and funds.	Propose sharp break between extent of Government and private enterprise work in this field—propose AEC program be limited to construction of prototype and experimental reactors and provision of commercial size would be responsibility of industry entirely.	Seriously concerned lest national objectives and policies on technical programs are determined by ad hoc committees, conferences of industrial representatives, magazine polls, etc., as substitute for determination by competent individuals responsible for implementation.

TABULAR SUMMARY OF REPLIES TO JCAE LETTER OF AUGUST 22, 1958—Continued

REACTOR EXPERTS—Continued

Name of company	1. Do you agree with the 3 major objectives (p. 4) of the program? If not, what changes would you recommend?	2. Are the general technical objectives (p. 5) adequate? If not, what additions or deletions would you recommend?	3. Please comment on the adequacy of the scope of the technological program (p. 6).	4. In your opinion, is the proposed list of reactors in table I the best list for this program? If not, what changes would you recommend?	5. Do you consider the cost estimates (p. 8) to be reasonable? If not, please point out the areas in which you disagree.	6. What is your opinion of the policies on organization and administration proposed on p. 9? Will they adequately implement the positive leadership required for success of the program?	7. If it should later prove necessary, what other types and amounts of assistance would you recommend for the domestic program? For the foreign program?	Additional remarks
Weinberg, Alvin M., Director—Oak Ridge National Laboratory.	Add economic power breeding as objective. Short-term future of nuclear power is not of crucial importance.	Set forth set of technical objectives for each type of reactor. Add development of low-cost methods for extraction of uranium from phosphoria rocks and shales.	Set forth technical objectives for each reactor and set forth means for accomplishing each objective.	Revise list to increase emphasis on breeders and highly enriched liquid fuel reactors. (See detailed list.)	Estimate of $500/KWE is probably sound. Consider 1,000,000 kilowatts rather arbitrary—don't understand basis for arriving at this number. Consider statement of policy on expenditures a major step forward in program planning. Total of $1,750,000,000 considered ample for revised list of reactors recommended under item 4.	Agree completely that AEC must exert positive direction.	Object to waiver of capital charges for heavy water and fuel since this artificially promotes certain reactor concepts. Power demonstration program is not adequate to achieve success.	
Worthington, Hood, director, Technical division, E. I. du Pont de Nemours & Company, Inc.	Satisfactory. Of opinion that 1970 date will not be met. 2-year differential between United States and foreign too	Seem adequate. Choice of effort distribution must be made in way which allows for diversity of views. Recommend	Not enough basic research work.	Adequate.....	$700–$800 per kilowatt appears more likely than $500.	.....	.....	

	short. Don't recommend changes though.	adding ceramic work under natural uranium work.						
Young, Gale, vice president, Nuclear Development Corporation of America.	Cannot comment on aspects relating to United States world leadership. Reasonable if goal in United States refers to high-cost areas.	Appear well chosen. If fundamental reactor types were redefined (see 4), changes in emphasis would be necessary.	----------	List is not ideal. Urge that only natural uranium and plutonium breeder types be considered for central station use.	----------	Adequate. Must make use of best technical suggestions regardless of source and best use of industrial contractors.	May require further assistance in reprocessing, disposal, plutonium credit, etc., areas.	
Zinn, W. H., president, General Nuclear Engineering Corp.	----------	----------	----------	----------	----------	----------	----------	Since had full opportunity to comment, acting as consultant in preparation of program, consider it inappropriate to comment now by letter.

TABULAR SUMMARY OF REPLIES TO JCAE LETTER OF AUGUST 22, 1958—Continued

PRIVATE POWER COMPANIES AND ORGANIZATIONS

Name of company	1. Do you agree with the 3 major objectives (p. 4) of the program? If not, what changes would you recommend?	2. Are the general technical objectives (p. 5) adequate? If not, what additions or deletions would you recommend?	3. Please comment on the adequacy of the scope of the technological program (p. 6).	4. In your opinion, is the proposed list of reactors in table I the best list for this program? If not, what changes would you recommend?	5. Do you consider the cost estimates (p. 8) to be reasonable? If not, please point out the areas in which you disagree.	6. What is your opinion of the policies on organization and administration proposed on p. 9? Will they adequately implement the positive leadership required for success of the program?	7. If it should later prove necessary, what other types and amounts of assistance would you recommend for the domestic program? For the foreign program?	Additional remarks
American Electric Power Co., Inc., by Philip Sporn, president.	Yes, although they are not all inclusive. For example, bring atomic power development within framework of exploitation of conventional energy sources. Specify location for definition of competitive power. Program objectives should be provisional having definiteness for only 2 or 3 years.	Yes. Troubled by rigidity of detailed formulation of technical objectives and reactor types. More attention should be given to relative importance and timing of technical objectives.	----------	Skeptical about ability of any group to describe desirable future reactors.	More preliminary work is necessary before level of expenditures can be considered with confidence.	During transition from present to period of competitive power, AEC role should be constantly diminishing one. Most prototype and all large-scale reactors should not be part of AEC's job.	(a) Receipt of AEC research and development support should not require a commitment for the building of a reactor. (b) No further projects in which the AEC owns the reactor portion. (c) Most prototype and large-scale reactors should not be part of AEC's job. (d) To assure AEC financial assistance is used effectively, condition aid on basis of a 50-50 contribution by agency receiving aid. (e) Agencies outside AEC should be en-	Need a new high level technical evaluation group for continuous evaluation of program.

encouraged to undertake construction of uneconomic first or later generation large reactors.

(f) Where necessary, outright grants should be made to outside agencies to cover major portion of difference in costs.

(g) Use of grants should be worked out to avoid excessive grants and equitable treatment of public and private power. This may require change in sec. 169 of act.

TABULAR SUMMARY OF REPLIES TO JCAE LETTER OF AUGUST 22, 1958—Continued

PRIVATE POWER COMPANIES AND ORGANIZATIONS—Continued

Name of company	1. Do you agree with the 3 major objectives (p. 4) of the program? If not, what changes would you recommend?	2. Are the general technical objectives (p. 5) adequate? If not, what additions or deletions would you recommend?	3. Please comment on the adequacy of the scope of the technological program (p. 6).	4. In your opinion, is the proposed list of reactors in table I the best list for this program? If not, what changes would you recommend?	5. Do you consider the cost estimates (p. 8) to be reasonable? If not, please point out the areas in which you disagree.	6. What is your opinion of the policies on organization and administration proposed on p. 9? Will they adequately implement the positive leadership required for success of the program?	7. If it should later prove necessary, what other types and amounts of assistance would you recommend for the domestic program? For the foreign program?	Additional remarks
American and Foreign Power Co., Inc., by H. W. Balgooyen, vice president.	Generally agree. Dates seem somewhat arbitrary. The short time interval between economic power abroad and in United States seems optimistic.	Relation of technical objectives to 3 major program objectives is not clear. Reexamine program periodically to assure proper orientation relative to overall objectives. Believe early demonstration of competitive power will be attained most expeditiously by concentration on few most promising reactor types.	Agree	List seems very comprehensive.	Believe cost estimates are generous.	Don't believe AEC should construct large-scale plants. Initiative for installing full-scale or prototype plants should come from industry. Give AEC flexibility to consider unsolicited proposals.	Financial assistance covering a share of excess construction and operating costs is essential if nuclear power construction is to be accelerated. If necessary, modify sec. 169. If assistance can only be provided under conditions where AEC owns facility, revise sec. 44 to remove discrimination against investor-owned utilities. Re foreign program—solution to 3d-party liability problem is especially important.	
Commonwealth Edison Co., by Willis Gale, chairman.	----------	----------	----------	----------	----------	Believe that joint ownership of nuclear power projects is a	Add contribution in form of a grant not to exceed 90 percent	

						costly, complicated, and inefficient way to advance the program.	of estimated cost difference between nuclear and conventional plants. This would involve consideration of revision of sec. 169 of act.
Commonwealth Edison Co. by T. G. LeClair, manager of research and development.	Reword objectives to indicate achievement of competitive nuclear power in free-world nations and in high-cost fuel areas in the United States in the early future and achieve competitive power in substantial part of United States by 1970.	----------	----------	Consider omission of rating figures for reactors for later years to reduce the degree of firmness of these projects.	----------	----------	(*a*) Add to list of AEC assistance on p. 10 a contribution in the form of a grant not to exceed 90 percent of the estimated conventional plant cost difference. (*b*) Believe that joint ownership of reactor plants is undesirable. (*c*) Eliminate construction of Government-owned plants other than at AEC sites where electrical power can be consumed for site operations.
Consolidated Edison Company of New York, Inc., by J. F. Fairman, senior vice president.	(*a*) Suggest adding explicit statement as 4th objective that the ultimate goal is to develop commercial plants which are economically competitive without financial assistance from Government. (*b*) Qualify target dates as hopes rather than firm expectations.	Suggest adding objective of "cheaper safety." (Eliminate ultra-conservatism in containment, shielding, etc., design.)	----------	Dates associated with power reactors for new undertakings may be rather optimistic.	----------	Allow more time for submission of proposals.	Special arrangements for assistance as provided for will probably be necessary.

TABULAR SUMMARY OF REPLIES TO JCAE LETTER OF AUGUST 22, 1958—Continued

PRIVATE POWER COMPANIES AND ORGANIZATIONS—Continued

Name of company	1. Do you agree with the 3 major objectives (p. 4) of the program? If not, what changes would you recommend?	2. Are the general technical objectives (p. 5) adequate? If not, what additions or deletions would you recommend?	3. Please comment on the adequacy of the scope of the technological program (p. 6).	4. In your opinion, is the proposed list of reactors in table I the best list for this program? If not, what changes would you recommend?	5. Do you consider the cost estimates (p. 8) to be reasonable? If not, please point out the areas in which you disagree.	6. What is your opinion of the policies on organization and administration proposed on p. 9? Will they adequately implement the positive leadership required for success of the program?	7. If it should later prove necessary, what other types and amounts of assistance would you recommend for the domestic program? For the foreign program?	Additional remarks
Detroit Edison, by Walker L. Cisler, president.	Basically agree. Dates should be flexible. Suggest 4th objective: "Establish criteria for selection of sites for atomic power and other atomic facilities."	Suggest rearrangement and addition of item on safety standards.		All worthy of study—construction should await careful evaluation of studies. AEC should be given maximum flexibility in what reactors are to be built. Suggest start of design of second generation fast breeder in 1961.				
Duke Power Co., by O. J. Miller, executive vice president.								See Edison Electric Institute reply.
Edison Electric Institute, by Elmer H. Lindseth, chairman, committee on atomic power.	(*a*) Believes that fortification of United States world leadership is primary objective and should be stated first. (*b*) Recommend adding 4th objective in keeping with sec. 1 of act to maxi-			Mere listing of reactor proposals in table I by the Joint Committee lends such weight and authority to them that it makes deviation or modification, as indicated by latter research, difficult.		(*a*) Important to provide flexibility in administration and technical decisions. Such flexibility is more easily achieved in administrative agency than in Congress. (*b*) Provide for	(*a*) Feel that Government assistance should not be limited to specific items but rather should ecompass whatever reasonable assistance proposer finds it necessary to request.	

	mize participation by private enterprise. (c) Question assignment of specific years for attainment of competitive power. Suggest "earliest practicable dates." (d) 5-year span between United States and foreign attainment is more realistic. (e) Need clarification in definition of competitive cost.					transfer of responsibility from AEC to industry as rapidly as feasible. (c) Believe better results are obtained by decentralization of decision making and where opportunity for industrial initiative and competition is provided for. Pp. 9 and 10 set stage for detailed and virtually exclusive Government control and directly contrary to the spirit of the act which was designed to give industry greater not less participation. (d) Suggest adding par. 6 on p. 11 to establish procedure for obtaining industry participation for projects designated by AEC.	(b) Basically undesirable to have federally owned plant on public or private utility system. AEC ownership should not extend beyond reactor experiments or small reactors at Commission sites. (c) If further speedup of program is considered necessary it is likely that types of assistance on p. 10 will not be adequate to get additional industry effort. Such assistance should be provided in such amounts and types to assure undertaking of projects by industry on competitive basis.	
General Public Utilities Corp., by E. W. Morehouse, vice president.	There is need for definition of "demonstrate" and recognition of conventional power cost differences in program objectives.	----------	----------	Building of full-scale plant is overemphasized as compared to smaller sized plants until competitive cost margin has been narrowed.	----------	----------	----------	Generally, concur in comments of Pennsylvania Electric Co.

TABULAR SUMMARY OF REPLIES TO JCAE LETTER OF AUGUST 22, 1958—Continued

PRIVATE POWER COMPANIES AND ORGANIZATIONS—Continued

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Middle South Utilities, Inc., by H. F. Sanders, vice president and secretary.	----------	----------	----------	----------	----------	Industry should be encouraged to take initiative in proposing reactor projects to AEC rather than to have AEC designate projects.	----------	EEI reply reflects Middle South's view.
New England Electric System, by William Webster, executive vice president.	Substantially agree.	Substantially agree.	Eliminate unpromising leads as program progresses.	Believe (list) contains today's most promising types. Eliminate unpromising developments as indicated by program results.	Believe that new developments will be undertaken by private capital at an accelerated pace as program proceeds and Government costs will correspondingly decrease.	Seems undesirable for AEC to construct full-scale plants until reactor concept has been carried well along in research and development stage and translated to prototype plant at AEC site. If AEC construction of large-scale plant becomes necessary, it should be carried out on a nondiscriminatory basis as between public and private systems.	----------	
Niagara Mohawk	Yes	Yes	Adequate	Adequate	Reasonable			

Niagara Mohawk Power Corp., by E. S. Bundy, director.	Yes	Yes	Adequate	Adequate	Consider group making study is qualified to make such cost estimates.	Adequate as viewed at present time.		
Northern States Power Co., by Allen S. King, president.	Yes. Question desirability of setting specific dates for attainment of competitive power—feel this should be left to agency directing program to determine.	Adequate. Place emphasis on fuel-cycle cost.	Adequate. Step up efforts on fuel-cycle development.	No question regarding reactors listed. Mere listing by JCAE lends such weight and authority to them that it makes future deviation difficult. Do not believe JCAE intended to limit AEC by this listing.	Appear reasonable.	(a) Agree that AEC be responsible for conduct of base research and development program. (b) Suggest full recognition be given to possibility of industry initiation projects for acceptance by AEC. (c) Suggest tone be modified to give full discretion to AEC concerning time allowance for response to invitations.	(a) If further speedup is considered essential and industry is to be asked to explore certain untested concepts, then provision should be made made for extending research and development support. Feel that this can be done without Government investment in plant but merely by broadening interpretation of research and development costs. (b) Commitment to construct should recognize unexpected developments that may result in mutual agreement that it's unreasonable to construct. (c) If AEC has as part of its administration program the construction by Government of large-scale plants, the question of economic feasibility will ultimately be lost.	Program is very broad in scope and tremendously complex. Program would tend to invade area of administrative responsibility which should be left to AEC.

TABULAR SUMMARY OF REPLIES TO JCAE LETTER OF AUGUST 22, 1958—Continued

PRIVATE POWER COMPANIES AND ORGANIZATIONS—Continued

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Ohio Edison Co., by Walter H. Sammis, president.	(a) Not sure of meaning of competitive cost since conventional fuel costs vary with area. (b) Objectives should be designed and stated to come within policy of Congress, sec. 1 of act. Accordingly, do not believe 1970 or any other predetermined year can be arbitrarily selected.	----------	----------	----------	----------	Don't believe AEC should be given exclusive right to select types of reactors.	----------	
Oklahoma Gas & Electric Co., by Donald S. Kennedy, president.	(a) Objectives appear sound although competitive power objective in United States is quite ambitious. (b) Can't agree with some in atomic field who	----------	----------	----------	----------	Policies seem reasonable—feel that written assurances should be included that Federal Government has no intention of continuing to direct or control	(a) Government's most valuable immediate contribution to private research would be dependable and prompt supply of special nuclear material and rare metals.	

							electrical industry when nuclear energy may become practical and economical.	(b) Recommend that no full-scale projects (except for limited experimental types) be sanctioned by Government or constructed by industry until value can be recaptured in approximately same time as for conventional types.
believe there is impelling rush about the whole program. (c) Believe various projects should be prosecuted by individual private utilities with whatever assistance can be lent by Government. Believe it is uneconomical to embark on construction of full-scale plants (except in isolated instances) during this investigation period.								

TABULAR SUMMARY OF REPLIES TO JCAE LETTER OF AUGUST 22, 1958—Continued

PRIVATE POWER COMPANIES AND ORGANIZATIONS—Continued

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Pacific Gas & Electric Co., by N. R. Sutherland, president.	Generally agree provided they are carried out to maximum practical extent by private enterprise.	Adequate.	AEC should concentrate on research and development and construction of small experimental types to demonstrate feasibility. Don't believe that Government construction of successive generations of full-scale plants is necessary.	Eliminate construction of large-scale and experimental reactors which would duplicate work underway.	Cost appears reasonable. Could be substantially reduced by elimination of reactors referred to under item 4.	Believe authority for construction should be limited to plant sizes required for technical feasibility demonstration.	Limit to research and development and construction of reactors only large enough to demonstrate technical feasibility.	
Penna. Electric Co., by Louis H. Roddis, Jr., president.	Yes. Subject to changing "demonstrate" to "prove through actual full-scale operation "and adding "some areas in" before "in the United States."	Yes. Suggest adding "(K) reduction in operating personnel requirements."	Adequate. Subject to comment in item 4. Suggest use of more positive statement than "consistent with security laws" relative to availibility of	(a) Suggest that both 200 magawatt pressurized and boiling reactors should provide for recognition of nuclear superheat. (b) Some projects should not be stated in such	Appear reasonable. Comparison on p. 13 (cost smaller compared to other Government expenditures) is quite illogical.	(a) Don't limit approaches to those in such a Government program—make adequate provisions for individual decisions and actions outside of framework of Government pro-	Construction differential grants, fuel guarantees, etc., all of which are susceptible to equitable distribution between public and private power, should be more thoroughly explored.	

			military and maritime reactor information to civilian program.	positive terms. Aqueous homogeneous believed to be premature. Last 5 reactors in table I stated in too definite terms—probably should be stated now only as "5 large-scale second generation central station plants."		gram. (*b*) Single-minded, responsible, technical direction with sufficient flexibility to permit rapid capitalization on new developments is needed. Detailed program authorized by Congress limits flexibility, although in present framework perhaps no other course is satisfactory. (*c*) Distribution of power to private companies from Government-owned plants may be difficult phase to administer in view of precise intent of sec. 44 of act.		
Philadelphia Electric Co., by L. R. Gaty, vice president.	----------	----------	----------	----------	----------	----------	----------	Reference made to Edison Electric Institute comments.

TABULAR SUMMARY OF REPLIES TO JCAE LETTER OF AUGUST 22, 1958—Continued

PRIVATE POWER COMPANIES AND ORGANIZATIONS—Continued

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Southwestern Electric Power Co., by J. Robert Welsh, president.	(*a*) Don't agree with 1970 date. Change objective "a" to indicate goal of achievement of low-cost power in United States with hope it will become competitive. (*b*) Statements in print show that program objectives will not be expedited by schedule in table I and that power per se will become the only objective since schedule is	Provide for addition of more technical objectives if progress indicates they are needed.	Don't agree with need to consrtuct full-scale reactors. If experiments and prototypes indicate competitive power is within reach, private industry will build.	Don't include full-scale reactors.	Act should be amended to provide grants of Federal funds for construction of plants under proposed program. If program is adopted costs to Government will be considerably greater than estimated.	Refer to EEI comment. Fail to see how sec. I of act can be observed without provision for adoption of private enterprise projects.	See item 5.....	Subscribe to EEI comments.

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TABULAR SUMMARY OF REPLIES TO JCAE LETTER OF AUGUST 22, 1958—Continued

PRIVATE POWER COMPANIES AND ORGANIZATIONS—Continued

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Texas Atomic Energy Research Foundation, by J. B. Thomas, president.	(a) Believe that present methods of calculation result in unrealistically low estimates of cost and, therefore, date for achievement of competitive power will be later than generally predicted. (b) Agree that United States should lead in technical program but believe that disproportionate interest on electric power since fuel costs for electrical power are only 14 percent of national fuel budget.	Objectives appear to cover present specific difficulties; hope that support won't be diverted from new concepts which may make present problems irrelevant.	----------	Since most reactors appear to be based on enriched uranium they cannot contribute to commercial cost information until actual (commercial) cost of enrichment has been disclosed.	----------	Agree. ----------	Considering private electrical industry's present dollar outlay (ca. $400,000,000) there appears to be a serious displacement of emphasis since electrical industry fuel requirements are only 14 percent of total. Recommend JCAE determine proportions by which various sectors are contributing to stimulate parallel efforts.	

Union Electric Co., by E. L. Hough, vice president.	Yes.	Yes.	Program compressed too much with emphasis on construction and insufficient time between generations to factor in experience.	Choice between reactor types and particular construction to be undertaken are matters which logically belong in the hands of a group such as AEC. List in table I appears sufficiently inclusive.	Reasonable range.			Concur in EEI comments.
Utah Power & Light Co., by G. M. Gadsby chairman of the board.	(*a*) Don't subscribe to fixing of dates for successful results. (*b*) Affirmative declaration of adhering to free-enterprise system might well be added as 4th objective.	Appears objectives are adequate for present. May add development of sufficient burn-up life to make reprocessing unnecessary.				Appears to give too much power of direction to AEC in future research and development. Question desirability of committing AEC to construction of projects which by reason of lack of technological data or economic promise would not be undertaken by others.	Emphasize desirability of changing secs. 44 and 169 of act.	

TABULAR SUMMARY OF REPLIES TO JCAE LETTER OF AUGUST 22, 1958—Continued

PUBLIC AND COOPERATIVE POWER COMPANIES AND ORGANIZATIONS

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American Public Power Association, by Alex Radin, president, and James Grahl, director, atomic energy service.	Suggests following changes to make objectives more challenging and specific: (*a*) Fortify United States position (place 3d objective 1st); (*b*) Benefit American consumer by low-cost power development and other peaceful uses of atomic energy; (*c*) achieve and demonstrate in United States nuclear power at 8 mills (proper number to be set on advice of reactor experts) or less by 1964 with plutonium at $12 per gram or less.	Yes	Scope adequate with following additions: (*a*) develop several types of small (10 to 20 megawatts utility plants; (*b*) stress large-scale plant development and sufficient reactor construction and operation for development value of large type and lower costs attendant increased volume demand for components.	(*a*) Seems possible to make more rapid progress by scheduling large pressurized and boiling water and 50 megawatts organic in 1959-63. (*b*) Add 3 or 4 small prototype plants of 15 to 40 megawatts for 1959-63.	Costs appear reasonable for program which is too conservative for "expanded" program.	(*a*) Positive AEC direction is essential. Believe it's a mistake to continue dependence almost entirely in 1st instance on "partnership" approach. In addition to experimental prototypes, a selected number of 2d and 3d generation plants should be scheduled definitely as Federal projects. (*b*) Suggest addition of construction of 2d generation plants at municipal, State, and rural cooperative sites with arrange-	If policies and procedures in the program are carried out there would be no need for further Federal subsidies to private industry—accordingly, it would be desirable to delete entire paragraph under "Other Considerations," p. 12.	

						ments similar to 2d round demonstration program. (c) Under B.1 add AEC designated 15 to 40 megawatts plants with arrangements similar to 2d round.	
California Department of Water Resources, by Harvey O. Banks.	Yes. Define competitive cost numerically with a standard of load factor and financing method.	Yes	Suggest greater emphasis on low-temperature process			Appear sound	
Consumers Public Power District, by R. L. Schacht, general manager.	State as an objective that several reactor types should be carried through to completion in lieu of continually discarding types which have a lesser chance of being cheapest. Further define "competitive in costs" by stating areas.	Add investigations to lower operating costs.	Add policy statement relative to schedule for proceeding with generations of each type.	Appears best—evaluate annually.	Construction cost may reach $600,000,000 with a potential increase of $300,000,000. Design and development subject to same cost increases.	Agree in necessity of aggressive direction by AEC.	Broaden definition of research and development. Suggest funds be used to defray predetermined percentage of plant costs in excess of conventional plant.

TABULAR SUMMARY OF REPLIES TO JCAE LETTER OF AUGUST 22, 1958—Continued

PUBLIC AND COOPERATIVE POWER COMPANIES AND ORGANIZATIONS—Continued

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Los Angeles Department of Water and Power, by William S. Peterson, general manager.	Yes. Suggests definition of "competitive nuclear power in the United States" by tying it to high-cost regions of California, Florida, and New England based on private financing of the plants.	Yes. Special emphasis on cheaper components, cheaper field assemblies and better fuel elements.	More than adequate. Programs for unproven concepts too ambitious. Divert moneys from unproven concepts to 2d and 3d generation proven concepts.	Following reactor plants should be undertaken: (1) Gas-cooled graphite moderated; (2) boiling water with nuclear superheat; (3) process heat reactor; (4) intermediate energy neutron breeder; (5) water-cooled, graphite-moderated Hanford type; (6) pressurized water enriched uranium fuel; (7) boiling water enriched uranium fuel; (8) organic-cooled reactor; (9) high-temperature, gas-	Adequate.....	Endorse. Also believe long-range (15-year) plutonium buy-back will implement basic policy.	Role of municipal or cooperative utilities not clear. May be construed they become part of program by default of private utilities. Believe that 2d round extension will help.	

				cooled, graphite or heavy water moderated; and (10) sodium-cooled fast or intermediate breeder. Others be research and development consideration in national or university labs.				
National Rural Electric Cooperative Association, by Paul Nelson, staff economist.	The 1968 and 1970 goals for competitive power are not consistent with the maintenance of a position of leadership by the United States considering the rapid progress being made by other foreign nations.	Adequate and well chosen.	Object to lack of specific reference to development of several types of smaller reactors in 10- to 40-megawatt range for use by co-ops, municipalities, and public utilities. Believe that only through power per se and volume production substantial cost reductions be attained.	Time schedule is conservative—should be accelerated.	Suggest greater expenditures.	AEC must exert more forceful and positive leadership. Partnership approach is not satisfactory. Federal Government should construct several projects. Object to proposal that prototypes be constructed at municipal, State, or co-op sites only when no satisfactory proposal is received since this would effectively exclude cooperation by consumer owned utilities and help create a monopolization by commercial utilities.	Oppose any change to secs. 414 and 169 of act and any additional forms of assistance.

TABULAR SUMMARY OF REPLIES TO JCAE LETTER OF AUGUST 22, 1958—Continued

PUBLIC AND COOPERATIVE POWER COMPANIES AND ORGANIZATIONS—Continued

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Rural Cooperative Power Association, Elk River, by Edward E. Wolter, manager.	Accomplish demonstration of competitive power for foreign markets by doing work in United States with American engineers and manufacturers in selected (high cost) United States areas. "Item C establishes a responsibility of the United States as in charge of sales of atomic energy and particularly with regard to power."	Suggest construction of plant or 2 in area where facilities dedicated to safeguards could be minimized to get more realistic figures when conventional practices are followed.	----------	----------	Until safeguards committee releases their requirements through experience, it will be extremely difficult to improve any cost per kilowatt.	Agree----------	Methods stated should be adequate.	

Tennessee Valley Authority by Herbert D. Vogel, Chairman of the Board.	Doubtful that 2-year interval between United States and foreign dates is adequate—feel that 1968 date could be advanced but it may be necessary to make 2d date later.	Agree. Emphasize improvement of fuel elements and cycles high conversion and breeding cycles.	Agree. Suggest including at least 1 project whose objective would be the eventual design of advanced plant to be competitive in; lowest cost United States power areas. Agree with objective of more effective military-civilian information exchange.	----------	----------	Agree with need for positive AEC direction.	----------	Believe Federal power agencies should not be excluded from ownership of plants or contractual participation in development of Government constructed plants. (Change program accordingly.) Reference fusion power work in program.
U. S. Department of Interior, Bonneville Power Administration, by Wm. A. Pearl, Administrator.	Objectives are reasonable. Recommend 1965 as foreign goal.	Consider development of fuel cycles for long-range economic basis more important than building in the near term a large number of uneconomic or marginal plants. Fossil fuel reserve justifies this approach. Long-range effort should be directed to breeding.	Adequate.	Include pebble bed reactor in high temperature, gas-cooled concept.	----------	Appears sound.	----------	
Wolverine Electric Cooperative, by John N. Keen, manager.	----------	----------	----------	More work should be done on small prototype reactors.	----------	----------	----------	

TABULAR SUMMARY OF REPLIES TO JCAE LETTER OF AUGUST 22, 1958—Continued

ARCHITECT-ENGINEERS

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Associated Nucleonics, Inc., by W. E. Kelley, president.	Agree in general but if it takes 10 years for foreign countries believe it will take more than additional 2 for United States. Believe nuclear power can't become competitive on large scale in United States before 1973.	All are important to a degree. Feel that there will not be general agreement on relative emphasis.	Agree in general. Pitfalls result from Government subsidies which hide fact that plants are not really competitive.	Good list provided it's not frozen.	Appear more than adequate.	Agree. Congress must make certain that AEC staff does not tie itself too strongly to scope but remains open to accept novel reactor proposal.	----------	
Bechtel Corp., by J. P. Yates, executive vice president.	Objectives are sound.	----------	----------	----------	----------	----------	Urge full consideration of construction grants for "intermediate generation" power reactor prototype.	Program is generally sound.

Blaw-Knox Co., by Bruce Alexander.	Agree	Making "cheaper components" a secondary goal in unproven plants can defer proving plants indefinitely.	Agree	Satisfactory	Reasonable	Agree	Adequate	
Burns & Roe, Inc., by R. C. Roe, president.	Does not indicate area in which costs are competitive. Experience by 1970 will be inadequate for comparison of competitive cost since conventional plant lives are 25 to 35 years.	Some fuel element development costs may be more productively spent on solving corrosion and mass transfer problems of homogeneous reactor. Suggest development of gas turbine prime mover.	Emphasize need for homogeneous development.	Consider use of gas cooling in bismuth-uranium and fused salt reactors. Consider also uranium hexafluoride gas reactor.	Considering time periods and sizes $600 to $650 per kilowatt might represent a better overall average for period.	Policies are sensible.	Consider adding assistance in form of operation training.	
Catalytic Construction Co., by T. Ellwood Webster, president.								Concur in general.
Commonwealth Associates, by E. V. Sayles, vice president.	Yes	Adequate	Adequate	Maintain maximum flexibility in types on list.	Reasonable	Point out that lack of proposals could be because reactor may not be promising type. It would be wrong to require AEC to build such a type.		

TABULAR SUMMARY OF REPLIES TO JCAE LETTER OF AUGUST 22, 1958—Continued

ARCHITECT-ENGINEERS—Continued

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Ebasco Services, by Leonard F. C. Reichle, nuclear engineering director.	General: Two distinct objectives exist: (1) short-term demonstration or determination of conditions for economic power and (2) long-term development of advanced technology for future plants. Specific: Dates are somewhat arbitrary and not essential—no strong objection though. Agree main target should be attainment of competitive power in United States. Phrase "competitive in cost" rather	The 10 objectives do not appear to represent definable goals, but areas of worthwhile investigation. (Comments on which objectives appear short term and long term.) Should probably add nuclear safety with emphasis on kinetics and objectives relative to fluid fuel, process heat, epithermal and unmoderated reactor concepts.	Make distinction between short- and long-term goals. Believe that industry should participate as responsible partner in construction and operation of every proto and full-scale reactor.	Believe table includes major reactor types which should be considered. Selection of reactor types for construction should be made in accordance with short- and long-term objectives—select not more than 3 for short term. Continual review of list is necessary.	Adequate.....	Positive AEC leadership needed. Object to establishment of deadlines for initiation of a project. Don't like to see obligation to proceed with construction if project is highly speculative.	Don't believe present types of assistance are adequate—urge immediate consideration of plan which does not discriminate against investor-owned utilities. Plan should provide for payment of portion of excess building and operating costs without requiring relinquishment of management control by sponsor. Don't consider it prudent to provide hidden subsidies such as attractive prices for materials and services.	

	vague. 2-year difference between United States and foreign is optimistically short.						Solution to 3d party liability problem is of major importance to foreign program.
Fluor Corp., by P. W. Parnell, chairman of the board.	Not clear on significance of 1970 date. Of opinion that nuclear power will be competitive before 1970 in some United States areas and after 1970 in others. Question statement that we occupy position of world leadership considering Britain's accomplishment. Qualify world leadership or eliminate.	Question necessity of "cheaper field assembly"—these operations are mechanized to point where there is very little room for improvement.	Appears that opportunities to reduce overall costs are greater by lowered fuel cycle costs than reduced capital costs. Place special emphasis on higher temperatures and pressures for steamcycle.	----------	----------	Believe that lowest cost for program could be achieved by working exclusively with private utilities and not imposing financial penalties on them. Government could underwrite differential capital and construction cost.	Refer to item 6 for domestic program. Assistance outlined for foreign program are adequate.
Gibbs & Hill, Inc., by David B. Sloan, president.	Agree generally. Omit 1970 for domestic and State "as rapidly as possible." Omit 1968 and substitute "within the decade."	Agree generally	Agree	Would like to see "high temperature" or "superheat" appear more frequently.	Agree. Should be flexible.	Satisfactory	Covered adequately.
H. K. Ferguson Co., by Edward L. Heller, chief, reactor projects.	Shorten time schedule. Try for 10-mill power by 1963 which would be competitive with foreign markets and 8-mill power by 1965 which would be competitive in high cost United States regions.	Adequate	Adequate	Add the construction of three 25 to 75 thermal megawatt reactors of proven design in 1959 to 1960 period.	Adequate	----------	If necessary consider adding a payment toward capital costs and subsidy on fuel elements.

TABULAR SUMMARY OF REPLIES TO JCAE LETTER OF AUGUST 22, 1958—Continued

ARCHITECT-ENGINEERS—Continued

Name of company	1. Do you agree with the 3 major objectives (p. 4) of the program? If not, what changes would you recommend?	2. Are the general technical objectives (p. 5) adequate? If not, what additions or deletions would you recommend?	3. Please comment on the adequacy of the scope of the technological program (p. 6).	4. In your opinion, is the proposed list of reactors in table I the best list for this program? If not, what changes would you recommend?	5. Do you consider the cost estimates (p. 8) to be reasonable? If not, please point out the areas in which you disagree.	6. What is your opinion of the policies on organization and administration proposed on p. 9? Will they adequately implement the positive leadership required for success of the program?	7. If it should later prove necessary, what other types and amounts of assistance would you recommend for the domestic program? For the foreign program?	Additional remarks
Jackson & Moreland, by John R. Coffin, vice president.	Specifically indicate goal is for plants competitive with 10 percent of total thermal capacity added in 1970 in United States.	Suggest scope be increased to include cycle simplification by greater emphasis on using coolant as prime mover working medium, develop high reactor and prime mover energy densities and low enrichment elements to withstand 1,600° F. to 1,800° F. and 10,000 MWD/T.	Change consistent with item 2.	Consider high pressure and temperature, light water moderated, gas-cooled reactor in combination with closed cycle gas turbine should be considered.	Reasonable	Agree	If not adequate a direct subsidy may be necessary.	
J. A. Jones Construction Co., by Edwin L. Jones.	Agree	Yes	Adequate	Recommend AEC build reactor at each of its major installations to supply power for operations and for development.	Certainly is an educated guess.	AEC must furnish positive leadership.	Depends on developments.	

Kaiser Engineers, by Patrick J. Selak.	----------	----------	----------	----------	----------	----------	----------	No comments to add at this time.
Pickard- Warren-Lawe Associates, by James K. Pickard.	Worthwhile and reasonable to expect that they can be accomplished in allotted time.	Provisions should be made changing them as indicated desirable by frequent review.	Inherent inflexibility of detailed program sanctioned by Congress and others causes unnecessary expenditures in continuing projects originally planned which experimental results indicate should be terminated and unnecessary delay in undertaking new projects which experience indicates desirable.	The list is long—believe that overall objectives can be more rapidly accomplished by concentrating 1, 2, or perhaps 3 types.	Considerable expense can be saved without jeopardizing objectives by reducing number of large plants and limiting work on unproven type.	Important that United States industry, utilities engineers, and manufacturers participate in direction of even the experimental and feasibility work to greater extent than indicated in program. AEC lacks qualified and experienced administrative personnel in power field to assume entire responsibility of selecting demonstration reactors, establishing schedules, etc.	Believe modification and expansion of power reactor demonstration program by increased AEC support of reactors selected by industry is more practical—understand different interpretation of "no subsidy" provision of act may be involved. Recommend straight cost sharing between AEC and industry.	Proper for Congress to establish such objectives. Not feasible or desirable for Congress to define nature of program in detail.
Sanderson & Porter.	Agree. Believe domestic and foreign program are one and same. Suggest combining objectives into one.	Need development of reactors producing high temperature working fluid and high conversion ratios and breeding which eliminates U–235 burner reactors. Reactors which do not meet breeder objectives should be deemphasized and money spent on more advanced types.	Agree. ----------	List must be flexible and subject to change. Gas-cooled reactor is not being given enough emphasis. Believe that gas turbine reactor type should be included.	----------	Agree. Recommend program be conducted to build a broad base of manufacturing and engineering firms.	Believe that only assistance needed from Government is basic research and development and construction of experimental types.	

TABULAR SUMMARY OF REPLIES TO JCAE LETTER OF AUGUST 22, 1958—Continued

ARCHITECT-ENGINEERS—Continued

Name of company	1. Do you agree with the 3 major objectives (p. 4) of the program? If not, what changes would you recommend?	2. Are the general technical objectives (p. 5) adequate? If not, what additions or deletions would you recommend?	3. Please comment on the adequacy of the scope of the technological program (p. 6).	4. In your opinion, is the proposed list of reactors in table I the best list for this program? If not, what changes would you recommend?	5. Do you consider the cost estimates (p. 8) to be reasonable? If not, please point out the areas in which you disagree.	6. What is your opinion of the policies on organization and administration proposed on p. 9? Will they adequately implement the positive leadership required for success of the program?	7. If it should later prove necessary, what other types and amounts of assistance would you recommend for the domestic program? For the foreign program?	Additional remarks
Sargent & Lundy Engineers, by A. Kolflat.	Yes	Adequate. Suggest critical review of costs primarily attributable to safety aspects, simplification of licensing procedures to reduce costs, lower cost of personnel training and licensing.	Agree	Wide range of reactors raises question of how effective program might be in achieving competitive cost in time period allowed.	Appears adequate	Logical	Doubtful if incentives are adequate to encourage installation of privately owned plants for this program. In addition to assistance now offered consider outright grants to absorb major portion of excess costs—for both operating and capital costs. (Examples of additional assistance also suggested.)	
United Engineers & Constructors, by A. C. Middleton, vice president.	Agree	Agree. Suggest low-cost process for manufacturing low enrichment fuel.	Adequate	Satisfactory	Reasonable	Policies outlined are necessary. Greater stress should be placed on encouragement to public utilities.	Strongly recommend consideration of financial assistance to public utilities in form of cost difference between conventional and nuclear.	

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